ON SOME POINTS

IN THE

COMPOSITION OF WHEAT-GRAIN, ITS PRODUCTS IN THE MILL, AND BREAD.

BY

J. B. LAWES, F.R.S., F.C.S, AND J. H. GILBERT, PH. D., F.C.S.

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The composition of the grain yielding the most important article of human food in temperate climates, its yield of valuable products, and the varying composition either of the grain itself, or of these products, according to the conditions of growth, or the circumstances of after preparation, are subjects worthy the attention equally of states and of men of science. Accordingly we find, that a chemical examination of wheat-grain and its products, has from time to time been undertaken by chemists of repute; sometimes as a matter of private investigation, and at others of public inquiry; and almost as numerous as the names of the experimenters, are the special lines of research which they have selected.

We are indebted to Beccaria for the first notice, more than a century ago, of the gluten in wheat. Among the earlier investigators of the subsequent period, are, Proust, Vauquelin, De Saussure and Vogel, who have examined the proximate principles, and some of the changes to which they are subject, in various descriptions of wheat, of flour, or of bread. M. Boussingault has somewhat elaborately studied various branches of the subject more recently; and we are indebted to Dumas,

Payen, Johnston, and Dr. R. D. Thomson for original, as well as a considerable amount of collected information. The most recent, on some points the most detailed, and from advance in methods, perhaps on some also the most reliable, are the results of M. Peligot in 1849, on the proximate constitution of various kinds of wheat, and of M. Millon in 1849 and 1854, on somewhat similar points. Lastly, in 1853 M. Poggiale, and in 1855 Dr. Maclagan, have given the results of their investigations on the characters and composition of bread.

Besides these more general investigations, we have had in recent times many special inquiries connected with our subject. Thus, M. Boussingault has given us analyses of the ashes of wheat; and many other such analyses have been made in Germany, and elsewhere, since the first appearance, in 1840, of Baron Liebig's work on "Chemistry in its Applications to Agriculture and Physiology." In this country, Mr. Way has given us the most extensive series of wheat-grain-ash analyses, his list including those of 26 specimens or descriptions.

The plan of our own investigation, which unfortunately has been much less perfectly filled up than we at first intended, was entered upon more than a dozen years ago, and was devised with reference to the following points:—

1st. The influence of varying characters of season, and of various manuring, upon the organic and mineral composition of wheat grain.

2ndly. The characters of varieties, especially in relation to their adaptation, and the qualities they then develop, under the influence of broader distinctions as to locality, altitude, latitude, and varying climatic circumstances generally.

It is in the second branch of the inquiry that we have fallen the furthest short of our intentions. With a view to its prosecution, a journey through the chief corn growing districts of Europe, commencing at the northernmost point at which wheat is grown successfully, was about to be undertaken in 1848; but the social disturbances on the continent at that period, necessarily prevented it. The plan proposed was—to collect information, as to the geological and meteorological characters of the various localities, as to the mode of culture, and as to the general acreage yield, both in straw and grain; and lastly, to procure characteristic specimens for chemical examination at home. Failing entirely in the execution of this design, the Exhibition of 1851 was looked forward to as an oppor-

tunity for procuring specimens not only of wheat, but of other vegetable products, and perhaps also important particulars of their growth, from various countries and climates. Such, however, was the division of authority, and such the alleged preference given to public institutions in such matters, that, whether the latter benefited or not, the collection which we, as private individuals, were enabled to make, was entirely inadequate to our object. From these difficulties it is, that our second main object of inquiry was necessarily to a great extent abandoned; and chiefly for this reason, but partly owing to the pressure of other subjects; the first or more limited or local branch of the investigation has in recent years been but imperfectly followed up. And, as it is probable that it must for some time remain so, it has been thought desirable thus to put on record the results already obtained; hoping that they may serve the double purpose, of confirming or adding to previously existing knowledge, and of indicating to others the points most requiring further study.

The following is a brief outline of the plan of investigation which has yielded the results which we have now to lay before the Society.

From the season 1843–4, up to the present time, wheat has been growing in the same field continuously, both without manure, by ordinary, and by various chemical manures. As a general rule, the same description of manure has succeeded year after year on the same plot of land. The amount of produce, corn, straw, and chaff, and its characters as to weight per bushel, &c., have in every case, been carefully ascertained and recorded. Samples from each plot—both grain and straw—have also been collected every year. Of each of these samples two weighed portions are coarsely ground; the *dry matter* determined at a temperature of 212°; and the *ash* by burning on sheets of platinum, in cast iron muffles arranged for that purpose.* Other weighed portions of grain and straw are partially dried, so as to prevent their decomposition; and in this state they are preserved for any examination of their organic constituents. By this course of procedure, a vast mass of results has been obtained, illustrating the influence of season and manuring, upon the percentage of dry substance, and of mineral constituents, in the produce. In selected cases, the *nitrogen* in the grain, and in the straw, has been determined.

* The dry matter and ash, were not determined in such complete series in the earlier years, as in the later.

A summary table of these dry matter, ash, and nitrogen results, will be given below. In from twenty to thirty cases complete analyses of the grain-ashes have been made, and the results of these will be given in full.

Besides the experiments above described, in selected cases, chiefly from the produce of the earlier years of the field experiments, it was sought to ascertain the comparative *yield of flour*, and also the characters of the flour, of grain grown by different manures in the same season, or by the produce of different seasons. The *colonist's steel handmill* was first had recourse to for this purpose. But it was soon found, that it was extremely difficult so to regulate the machine, as to secure uniform action upon the different grains; and it was further found, that the grain, and especially the bran, was cut up rather than crushed, so as to leave too much of flour in the portion separated as bran, and too much of bran in that separated as flour; and hence the results were not sufficiently comparable with those of the ordinary mill. Arrangements were therefore made for prosecuting the inquiry at a flour mill in the neighbourhood, worked by water power. Weighed quantities of the selected samples (from 125 to 250 lbs. each), were passed through the stones, and the "*meal*" thus obtained, through the dressing machine, under our own personal superintendence; great care being taken to clear from the different parts of the apparatus the whole of one lot, before another was commenced upon.

The yield in the dressing machine of each of the different products was ascertained, and its percentage in relation to the total grain or its "meal," has been calculated. Portions of each of these products have had their dry matter (at 212°), and their mineral matter (by burning on platinum), determined. The percentage of nitrogen in a few selected series—from the finest flour down to the coarsest bran—has also been estimated; and in the same cases, the amounts of one or two of the more important constituents of the ash have also been determined. The results of these dry matter, ash, nitrogen, and constituent of ash determinations, in the series of different products obtained in the mill, will be given in tables further on.

The original design, was to complete the examination of the mill products, by determining in several series of them, the percentage of each of their proximate organic principles; and also the amount and composition of mineral matters, associated with

them respectively. It was hoped, by this latter inquiry, to obtain important collateral information, bearing upon the influence of various constituents upon the healthy and special development of the plant. Although, however, specimens of the flour are preserved for this purpose, as well as the ashes of each crude product, it is feared that this subject cannot be proceeded with, at least for a considerable time to come.

Portions of the different products of the dressing machine (including more or less of the finest flour, of the more granular, or of the more branny particles respectively), from grains of somewhat various history of growth, have been experimented upon to ascertain their comparative bread-making qualities; and these results, together with a few examinations of baker's bread, and a discussion of the results of other experimenters, as to the yield of bread from a given amount of flour, and the percentage of water and of nitrogen in the former, will be given below.

With this short outline of the plan of investigation which has been pursued, we proceed now to a discussion of the results which have been obtained.

In Table I. are given, in the first four columns, certain prominent characters of the produce of each of ten years of the successive growth of wheat as above described. The items are:—

The total produce per acre (corn and straw), in lbs.;
The per cent. of corn in the total produce;
The per cent. of dressed corn in the total corn; and,
The weight per bushel of dressed corn in lbs.

The figure given for each year, generally represents the average of about 40 cases; and the characters enumerated are the best which can be given in a summary and numerical form, to indicate the more or less favourable condition of the respective seasons for the healthy development of the crop, and the perfect maturation of the grain.

In the second set of three columns are given, side by side with the general characters just described, the percentages in the grain of each year—

Of dry substance;
Of ash in dry substance; and,
Of nitrogen in dry substance;

the two former items being in most cases the average of 30 to 40 cases in each year; but the per cent. of *nitrogen*, is in each instance, the mean of a few selected cases only.

In the third set of three columns, are given similar particulars relating to the composition of the straw. The percentages of dry substance and of ash in the straw, are however not the averages of so many cases in each year, as are those for the corn; and the determinations of nitrogen in the straw, have also been made in fewer cases than in the grain.

It will thus be seen, that the table affords a summary view of a really enormous amount of experimental result, and we ought to be able by its means to discover, at least the broad and characteristic effects of varying seasons, upon the composition of the crop.* This indeed is all we could hope to attain, in such a mere outline and general treatment of the subject as is appropriate to our present purpose.

TABLE I.

General Summary.

Harvests	Particulars of the Produce.				Composition of Grain.			Composition of Straw.		
	Total corn and straw per acre in lbs.	Per cent. corn in total produce.	Per cent. dressed corn in total corn.	Weight per bushel of dressed corn in lbs.	Per cent. dry (212°.)	Per cent ash in dry.	Per cent. nitrogen in dry.	Per cent. dry (212°.)	Per cent. ash in dry.	Per cent. nitrogen in dry.
1845	5545	33·1	90·1	56·7	80·8	1·91	2·25	..	7·06	0·92
1846	4114	43·1	93·2	63·1	84·3	1·96	2·15	..	6·02	0·67
1847	5221	36·4	93·6	62·0	..	..	2·30	..	5·56	0·73
1848	4517	36·7	89·0	58·5	80·3	2 02	2·39	..	7·24	0·78
1849	5321	40·9	95·5	63·5	83·1	1·84	1·94	82·6	6·17	0·82
1850	5496	33·6	94·3	60·9	84·4	1·99	2·15	84·4	5·88	0·87
1851	5279	38·2	92·1	62·6	84·2	1·89	1·98	84·7	5·88	0·78
1852	4299	31·6	92·1	56·7	83·2	2·00	2·38	82·6	6·53	0·79
1853	3932	25·1	85·9	50·2	80·8	2·24	2·35	81·0	6·27	1·20
1854	6803	35·8	95·6	61·4	84·9	1·93	2·14	83·7	5·08	0·69
Means	5053	35·4	92·1	59·6	82·9	1·98	2·20	83·2	6·17	0·82

Leaving then out of view all minor points, and confining ourselves to our already defined object—namely, that of ascertaining the general direction of the influence of variation of season upon the composition of the wheat crop—we cannot fail to see, that wherever the three items indicating the *quality* of the produce

* It should be stated, that up to 1848 inclusive, the description of wheat was the Old Red Lammas; from 1849 to 1852 inclusive, it was the Red Cluster, and since that time the Rostock. The variations, according to season, both in the characters and composition of the produce, are, however, very marked within the period of growth of each separate description.

markedly distinguish the crop as favourably developed, we have a general tendency to a high percentage of dry substance, and to a low percentage both of mineral matter, and of nitrogen, in that dry substance. This generalization is more especially applicable to the grain; but with some exceptions, mostly explicable on a detailed consideration of the circumstances and degree of its development, it applies to a great extent to the straw also.

Let us take in illustration the extreme cases in the table. The seasons of 1846, 1849, and 1851, with in the cases of the two latter large produce also, give us the best proportion of corn in total produce, more than the average proportion of dressed corn in total corn, and the highest weight per bushel—a very significant character. With this cumulative evidence as to the relatively favourable development and maturation of these crops, we find the grain in two of the cases, to be among the highest in percentage of dry matter; and in the third (1849), though not so high as we should have expected, it is still above the average. The percentages of mineral matter and of nitrogen in the dry substance of the grain, are at the same time, in these three cases, the lowest in the series. The seasons of 1850 and 1854 again, with large amounts of produce, yielded also very fairly developed grain; and coincidently they afford a high percentage of dry substance, and lower percentages both of mineral matter, and of nitrogen, in that dry substance, than the cases of obviously inferior maturation. With some exceptions, it will be seen, that the straws also of these 5 better years, give a tendency to low percentages both of mineral matter and of nitrogen in their dry substance.

Turning now to the converse aspect, the season of 1853, shows itself in the general characters of the produce, to have been in every respect the least favourable to the crop; and it should be added that in this instance (as well as in 1845 to which we shall next refer), the seed was not sown until the spring. In 1853 the produce of grain was small as well as very bad in quality; and with these characters, we have in the grain nearly the lowest percentage of dry matter, and the highest percentage of ash and of nitrogen in that dry matter. In the straw, too, the dry matter is low, the ash somewhat high, and the nitrogen much the highest in the series. In 1845, another year of spring-sowing, and at the same time of very bad quality of produce, we have nevertheless a large *amount* of growth; a fact which tends to explain some of the differences in composition as compared with 1853. Thus, 1845

gives us low percentage of dry matter, but not very high, either ash or nitrogen, in the grain. The straw, however, gives high percentages both of ash and of nitrogen; it being in the latter point next in order to 1853. The seasons of 1848 and 1852 again show low characters of produce. The former has coincidently the lowest percentage of dry matter in the grain in the series; and both have high percentage of ash and nitrogen in the dry substance of the grain. In the straw, the ash is in 1848 the highest, and in 1852 above the average; the nitrogen in dry matter of straw being however in neither instance high.

In several of the cases here cited, there are deviations from our general assumption on one point or other. But an examination in greater detail, would in most or all of them clear up the apparent discrepancy. When indeed, we bear in mind how infinitely varied was the mutual adaptation of climatic circumstances to stage of growth of the plant, in almost every case, it would indeed be anomalous, did we not find a corresponding variation on some point or other, in the characters or composition of the crop. Still, we have the fact broadly marked, that within the range of our own locality and climate, high maturation of the wheat crop is, other things being equal, generally associated with a high percentage of dry substance, and a low percentage of both mineral and nitrogenous constituents. Were we, however, extending the period of our review, and going into detail as to varying climatic circumstances, interesting exceptions could be pointed out.

It may be observed in passing, that owing to the general relationships of the amounts of corn to straw, and the generally coincident variations in the percentages of nitrogen in each, the tendency of all these variations is in a degree so to neutralize each other, as to give a comparatively limited range of difference in the figures, representing for each year, the percentage of nitrogen in the dry substance of the total produce—corn and straw together.

The tendency of maturation, to reduce the percentages of mineral matter, and frequently of nitrogen also, is not observable in corn crops alone. We have fully illustrated it in the case of the turnip; and our unpublished evidence in regard to some other crops, goes in the same direction. The fact is indeed very important to bear in mind; for it constitutes an important item in our study of the variations which are found to exist in the composition both of the organic substance, and of the ash, of one and the same crop, grown under different circumstances. We may particularly observe,

that the obvious reduction in the percentage of nitrogen in wheat-grain, the more, within certain climatic limits, the seed is perfected, is in itself a fact of the highest interest; and it is the more so, when we consider how exceedingly dependent for full growth, is this crop upon a liberal supply of available nitrogen within the soil.

Bearing in mind, then, the general points of relationship which have been established between the characters of the crop as to development and maturation on the one hand, and the percentage amounts of certain constituents on the other, let us now see—what is the general influence of characteristic constituents of *manure*, upon the characters and composition of our wheat crop, which is allowed to remain on the land until the plant has fulfilled its highest function—namely, that of producing a ripened seed?

In illustration of this point we have arranged in Table III, the same particulars as to general character of the crop, and as to the composition of the produce, from several individual plots during the ten years; instead of the average of the series in each year, as in Table I. The cases selected for the comparison are:—

1. A continuously unmanured plot;
2. A plot having an excess of ammoniacal salts alone every year;
3. The average of several plots, each having the same amount of ammoniacal salts as the plot just mentioned, but with it, a more or less perfect provision by manure, of the *mineral constituents* also.

It would be impossible to give the detail supplying all the results collected in this Table III; but perhaps it is only proper that we should do so, so far at least as the percentage of nitrogen in the dry substance of the grain is concerned.

TABLE II.

Determinations of Nitrogen per Cent. in the Dry Matter of Wheat Grain grown at Rothamsted.

Harvests	Experiments. 1	2	3	4	5	Mean.
Unmanured.						
1845	2·28	2·21	2·33	2·30	..	2·28
1846	2·11	2·12	..	..	..	2·11
1847	2·11	2·08	2·22	2·22	..	2·16
1848	2·33	2·34	2·32	2·37	..	2·34
1849	1·85	1·83	1·91	..	..	1·86
1850	2·07	..	2·10	2·07	..	2·08
1851	1·80	1·74	1·89	1·76	..	1·80
1852	2·31	2·23	2·33	2·31	..	2·31
1853	2·26	..	2·33	2·38	..	2·32
1854	2·06	2·06	1·98	1·96	..	2 01
Manured with Ammoniacal Salts only.						
1845	2·18	2·29	2·22	2·23	..	2·23
1846	2·18	2·12	2·29	2·19	..	2·19
1847	2·35	2·29	2·42	2·32	..	2·34
1848	2·39	2·41	2·39	2·49	..	2·42
1849	1·89	..	2·04	1·92	..	1·95
1850	2·13	..	2·08	2·19	..	2·13
1851	2·15	2·12	2·09	2·25	..	2·15
1852	2·41	2·50	2·44	2·58	..	2·48
1853	2·43	2·48	2·37	2·44	..	2·43
1854	2·31	2·22	2·31	2·37	..	2·30
Manured with Ammoniacal Salts and Mineral Manure. (Mixed Plots.)						
1845	..	..	..	..	..	..
1846	2·20	2·14	..	2·14	..	2·16
1847	2·34	2·38	2·40	2·42	2·44	2·40
1848	2·36	..	2·40	2·42	2·48	2·41
1849	1·96	1·97	2·10	2·07	..	2·02
1850	2·16	2·28	2·25	2·25	..	2 23
1851	2 00	1·98	2·02	1·92	..	1·98
1852	2·43	2·34	2·31	2·40	2·32	2·36
1853	2·30	2·34	2·29	2·28	..	2·30
1854	2·16	..	2·12	2·07	..	2·12

It is necessary to make a few remarks in reference to this Table of more than one hundred nitrogen determinations. They were made by the method of burning with soda-lime, and collecting and weighing as platinum salt in the ordinary way. Few, perhaps, who have only made a limited number of such determinations, then only on pure and uniform substances, and who have not attempted to control their work at another period, with fresh re-agents, or by the work of another operator, will imagine the range of variation which is to be expected when all these adverse elements are to have their influence. It is freely granted, that the variations shown in the Table between one determination and another, on one and the same substance, are sometimes more than could be desired. The following, however, are the circumstances under which they have been obtained. Experiments 1 and 2 were pretty uniformly made by the same operator, but not all consecutively, or with the same batch of re-agents. It was thought, therefore, that independently of any variations between the two determinations, it would be desirable to have results so important in their bearings, verified by others. Accordingly, samples of each of the ground grains were given under arbitrary numbers, to two other operators, and their results are recorded respectively in columns 3 and 4; and where a fifth determination is given, it is a repetition by one or other of the experimenters last referred to. We should observe, that we have found it almost impossible to procure a soda-lime that will not give more or less indication of nitrogen when burnt with an organic substance not containing it; and hence we have at length adopted the plan of mixing 1–2 per cent. of non-nitrogenous substance intimately with the bulk of soda-lime, igniting it in a muffle, moistening, and reheating it gently. After this treatment the soda-lime is free from ammonia yielding matter. It should further be remembered, that a ground wheat-grain is by no means an uniform substance. Indeed, as we shall show further on, some of the particles of which such a powder is composed, may contain half as much again of nitrogen as others; and thus any inefficiency in the grinding, or error in taking the portion for analysis, may materially affect the result. Notwithstanding all these circumstances, and the admittedly undesirable range of difference in the several determinations in some cases, it will be observed, that generally three at least of the numbers agree sufficiently closely, and in some cases the fourth also. In fact after all, a study of the detailed table, must give considerable confidence, at least in the direction of the variations between the *mean* results given in Table III, and in their sufficiency for the arguments founded upon them. With these remarks on the data, let us proceed with the discussion of Table III itself, which next follows;

TABLE III.

	Particulars of Quantity.			Particulars of Quality.									Composition of Grain.									Composition of Straw.								
	Total Produce (Corn and Straw) per acre in lbs.			Per Cent. Corn in Total Produce.			Per Cent. Dressed Corn in Total Corn.			Weight Per Bushel of Dressed Corn. lbs.			Per Cent. Dry (212°.)			Per Cent. Ash in Dry.			Per Cent. Nitrogen in Dry.			Per Cent. Dry (212°.)			Per Cent. Ash in Dry.			Per Cent. Nitrogen in Dry.		
	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.	Unmanured.	Ammoniacal Salts only.	Minerals & Ammoniacal Salts.
1845	4153	6246	...	34·7	31·7	...	90·9	90·4	...	56·5	56·2	...	81·2	80·0	80·9	1·93	1·69	1·99	2·28	2·23	...	...	...	...	...	...	...	...	0·92	...
1846	2720	4094	4668	44·4	45·2	42·4	94·7	94·1	93·6	63·7	63·8	63·1	84·0	85·2	84·1	2·03	1·88	1·91	2·11	2·19	2·18	...	...	...	...	...	5·84	...	0·63	0·71
1847	3025	4593	5479	37·1	37 1	36·0	91·6	93·1	93·1	60·9	61·5	62·3	...	...	...	...	...	...	2·16	2·34	2·40	...	...	...	5·97	5·55	5·33	0·74	0·74	0·70
1848	2664	3701	4861	35·7	38·0	36·6	88·8	88·9	89·3	57·3	58·1	58·7	...	81·2	80·4	2·14	2·00	2·02	2·34	2·42	2·41	...	...	...	8 03	6·77	7·01	0·69	0·62	0·84
1849	2843	4992	5619	43·2	42·9	40·5	98·1	94·8	95·4	61·4	62·3	63·7	82·3	82·7	83·0	1·90	1·71	1·81	1·86	1·95	2·02	82·1	83·9	82·5	7 26	6·13	5·97	0·80	0·85	0·82
1850	2721	4810	5877	36·8	35·8	33·2	95·6	94·2	94·2	60·6	60·2	61·2	83·8	84·3	84·4	2·07	1·90	2·01	2·08	2·13	2 23	82·6	85·7	84·4	7·21	5·47	5·67	0·83	...	0·94
1851	2710	5038	5583	40·0	39·0	38·1	89·5	91·0	92·3	81·1	61·9	62 6	84·3	84·5	84·0	1·98	1·82	1·87	1·80	2·15	1·98	84·3	84·9	84·4	8.78	5·58	5·60	0·75	...	0·82
1852	2457	4107	4970	35·0	32·1	30·6	90 9	92·6	92·1	56·6	55·9	56·5	82 6	65·7	83·5	2·11	1·91	1·98	2·31	2·48	2·38	82·8	83·3	82·6	7·41	5·85	5·99	0·93	0·69	0·79
1853	1772	2691	4913	20·2	23·8	26·8	74·3	75·2	89·5	45·9	48 6	51·9	80·1	80·4	80·9	2·62	2·08	2·13	2·32	2·43	2·30	81·8	80·9	81·2	6·50	8·15	5·96	1·27	1·29	1·03
1854	3496	5808	8311	38·9	38·1	34·7	93·9	94·0	95·6	60·8	60·5	61·9	84·7	84·8	85·1	2·01	1·79	1·89	2·01	2·30	2·12	83·3	84·3	84 1	6 26	4·74	4·92	0·75	0·56	0·75
	2856	4608	5564	36·6	36·2	35·4	90·6	90·3	92·8	58·5	58·9	60·2	82·9	83·0	82·9	2·07	1·65	1·96	2·13	2·26	2·22	82·8	83·8	83·2	6·80	5·78	5·81	0·84	0·84	0·82

A glance at this Table III, shows that the *quantity* of produce varies very much indeed in one and the same season, according to the manuring. With these great differences in the *quantities*, dependent on manuring, we have far less marked differences in the *quality* of this ripened crop, dependent on the same causes; and this, with some few exceptions, is the same whether we look to the columns indicating the general characters only, or the composition of the produce. That is to say, the same general distinctions between the produce of one season and another, are observable under the several varying conditions of manuring in each, as have been exhibited in the Table I of averages alone. In fact, season, or climatic variations, are seen to have much more influence than manuring, upon the character and composition of the crop.

We have said that, other things being equal, the percentage of nitrogen in our wheat-grain was the lower the more the seed was perfected; and we have also said, that nitrogenous manures greatly aid the development of the crop. But, an inspection of the columns of Table III which give the percentages of nitrogen in the dry substance of the grains produced under the three different conditions of manuring specified, shows us that there is almost invariably, a higher percentage of nitrogen where ammoniacal salts alone have been employed, than where the crop was unmanured. We also see that, almost invariably, there is a higher percentage of nitrogen where mineral manures as well as ammoniacal salts have been used, than in the produce of the corresponding unmanured plots. A closer examination shows, however, though the indication is not uniform, that there is nevertheless, an obvious tendency to a lower percentage of nitrogen, where the mineral constituents also have been employed, than where the ammoniacal salts have been used alone; aud with this, there is on the average, a somewhat higher weight per bushel, indicating higher degree of maturation. Then, again, what are the circumstances of these experiments, under which an increased percentage of nitrogen in the fixed substance of the produce, is obtained by a supply of it in manure? The unmanured plot with its low percentage of nitrogen in produce, is shown by the field experiments, to be greatly exhausted of the annually available nitrogen, relatively to the annually available mineral constituents required by the wheat crop. The plot, with the ammoniacal salts alone, is shown by the field results to be defective in the requisite and available minerals, relatively to the available nitrogen, and hence the crop

is grown under a relative excess of the latter. Again, the plots with mineral manures and ammoniacal salts together, received so far an excess of the latter, as to yield, with the minerals, a larger crop than the average of the locality under rotation, and larger also, than the average of seasons would ripen healthily. It is then, under these artificial and abnormal circumstances, of the somewhat unnaturally low percentage of nitrogen, from obvious defect of it in relation to the developing and maturing capabilities of the season on the one hand, and the obviously relative excess of it on the other, that we got an increased percentage of nitrogen in wheat-grain by the use of it in manure. Even under these extreme conditions, the range of variation by manuring is very small; and there is nothing in the evidence that justifies the opinion, that, within the range of full crops and healthy maturation, the percentage of nitrogen in wheat grain, can be increased at pleasure by the use of it in manure. That very opposite extremes of condition of soil-supply, may directly influence the composition even of wheat-grain, is however, illustrated in the percentages of mineral matter, as well as those of nitrogen, given in the table. Thus, taking the mean results only, we have with the relative excess of mineral constituents on the unmanured plot, the highest per cent. in the produce; with the greatest relative defect on the plot with ammoniacal salts only, the lowest per cent. in the grain; and with the medium relation in the other plots, the medium per cent. in the produce. Excepting, however, abnormal conditions, as already remarked, variation in climatic circumstances, has much greater influence on the percentage-composition of wheat-grain, than variation in manuring.

Let us now turn to the composition of the *ash* of wheat-grain. Independently of the defect of a sufficient number of published analyses of wheat-grain ash, a dozen years ago, when we took up the subject, it was then generally believed that the composition of the ash of vegetable produce, would vary considerably with the supplies of the different constituents in the soil; it was thought indeed, that according to the abundance of their presence, one base might substitute another, as for instance *soda, potash,* and so on. About the same time that we undertook a series of wheat-ash analyses, the ashes of various succulent vegetables were also analysed. This latter investigation led us to conclude, that the fixity of the composition of the ash of such substances, depended very much upon the degree of maturation of the produce; and in

fact that some constituents—soda and chlorine for instance—occurred in much larger quantities in the more succulent and unripe, than in the more elaborated specimens. It seemed to be perfectly consistent with this experience, to find in the ash of a comparatively perfected vegetable product like wheat-grain, a considerable uniformity of composition—such indeed as the analyses now to be recorded will indicate.

These analyses were made ten years ago by Mr. Dugald Campbell, and the late Mr. Ashford. And as, since that time, the methods of ash-analysis have in some points been improved upon, it will be well to give an outline of the plan then adopted: especially as it is by a consideration of the tendencies to error on some points, that we must interpret the bearings of the actual figures given. On this point we need only add, that Mr. Campbell fully concurs in the tenor of our remarks.

Method of Analysis:—Three portions of ash were taken.

No. 1. In this the sand, silica, and charcoal, phosphate of iron, phosphoric acid, lime, and magnesia, were determined. The ash was dissolved in dilute hydrochloric acid, evaporated to perfect dryness, moistened with hydrochloric acid, boiled with water, and the insoluble matter collected and weighed, as—*sand, silica, and charcoal*. To the filtrate, acetate of ammonia was added, and after digestion, the precipitate separated, dried, ignited and weighed —as *phosphate of iron*. To the filtrate now obtained, a solution of a weighed portion of pure iron dissolved in nitro-hydrochloric acid was added, then acetate of ammonia, and the mixture digested until the whole of the iron was precipitated as phosphate of the peroxide with excess of peroxide, from which was calculated the *phosphoric acid*. From the solution filtered from the phosphate of iron and oxide of iron, the *lime* was separated as oxalate and ignited as carbonate; and from this last filtrate, the *magnesia*, by phosphate of soda and ammonia.

No. 2. A second portion of ash was put into a carbonic acid apparatus, the acid, if any, evolved by means of nitric acid, and determined by the loss. The solution being filtered, sulphuric acid was separated by nitrate of baryta; and afterwards *chlorine* by nitrate of silver.

No. 3. To a solution of a weighed portion of the ash in hydrochloric acid, caustic baryta was added in excess, and the precipitate separated by filtration; the excess of baryta was then

removed by carbonate of ammonia, and the filtered solution evaporated to dryness, the residue heated to redness and weighed; water added, any insoluble matter deducted, and the remainder taken as chlorides of potassium and sodium; a solution of chloride of platinum was now added to separate the *potash;* the *soda* being calculated from the loss.

It is now admitted, that the separation of phosphate of iron from the earthy phosphates by acetate of ammonia as above described, is unsatisfactory; and it is probable the amounts given in the tables as phosphate of iron are too high, and if so, part of the difference should obviously go to the earthy bases. For a similar reason it is possible that the phosphoric acid determinations may be somewhat too high—also at the expense of the earthy bases. Then again, it is well-known that in practice the process for potash and soda, is one of some delicacy; and that the tendency of manipulative error is to give the soda somewhat too high. We conclude upon the whole, that our phosphoric acid determinations *may* be somewhat high; our phosphate of iron pretty certainly so; and probably the soda also; the other bases being, on this supposition, given somewhat too low.

The wheat-grain ash-analyses, 23 in number, and referring to the produce of three separate seasons, and of very various manuring, are given in the following Tables—numbered IV, V and VI respectively.

TABLE IV.

Analyses of Wheat-Grain Ash.

Harvest, 1844.

Plot Numbers	2	3	5	1	9		15	16	18	
Manuring, per acre	Farm-yard Manure; 14 tons.	Unmanured.	Superphosphate Lime, 700 lbs.	Superphosphate Lime, 700 lbs, Rape Cake, 150 lbs.	Superphosphate Lime, 616 lbs. Sulphate Ammonia, 65 lbs.		Superphosphate Lime, Potash and Magnesia, and Silicate Potash.	As 15, with Soda and Sulphate Ammonia, 65 lbs.	As 16, and Rape-Cake, 154 lbs.	Means.
					Analysis 1	Analysis 2				
Characters of the produce:—										
Per Cent. Corn in Total Produce ..	46·4	45·2	46·1	46·4	48·3		46·9	46·8	43·6	46·2
Weight per bushel of Dressed Corn (lbs.) .	59·2	58·5	58·2	59·0	62·2		62·0	62·5	62·0	60·4
Per Cent. Dry Substance in Corn (at 212°)	82·8	81·8	81·1	82·3	83·6		83·1	83·3	83·2	82·65
Per Cent. Ash in Dry Substance ..	2·06	2·17	2·25	1·88	2·00		2·02	2·03	1·96	2·05
Constituents of Ash:—										
Phosphoric Acid	48·13	50·84	51·02	50·48	49·92	49·98	50·39	51·43	49·28	50·16
Phosphate of Iron	2·56	2·45	2·62	2·10	2·32	2·55	3·00	2·54	2·75	2·54
Potass	28·91	30·22	29·37	27·40	29·06	29·45	29·09	28·33	28·53	28·93
Soda	·76	·00	·22	1·12	·90	·00	·00	·00	2·10	·57
Magnesia	11·84	11·04	11·81	10·10	10·84	10·36	10·86	11·38	11·38	11·07
Lime	3·77	3 00	3·18	2·71	3·39	3·73	3·17	3·31	3·48	3·30
Chlorine	Traces	·12	Traces	·52	·15	·11	·09	·21	Traces	·13
Silica, Sand, and Charcoal	2·64	2·72	1·49	5·45	2·57	2·21	1·86	1·47	1·70	2·45
Totals	98·61	100·39	99·71	99·88	99·15	98·39	98·46	98·67	99·22	99·15

TABLE V.

Analyses of Wheat-Grain Ash.

Harvest, 1845.

Plot Numbers	2	3	5A	5B	6	15	17		Means.
Manuring, per acre	Farm-yard Manure, 14 tons.	Unmanured.	Superphosphate Lime in 1843–44.		Superphosphate Lime 112 lbs. Sulphate Ammonia 112 lbs. Rape Cake 560 lbs.	Bone-ash 224 lbs. Hydrochloric Acid 224 lbs. Sulphate Ammonia 224 lbs.	Superphosphate Lime 224 lbs. Sulphate and Muriate Ammonia, each 112 lbs. Rape Cake 280 lbs.		
			Unmanured.	Carbonate Ammonia (Solution).			Analysis 1	Analysis 2	
Characters of the produce:—									
Per Cent. Corn in Total Produce ..	33·4	34·7	34·8	32·5	33·9	34·2	35·4		34·13
Weight per bushel of Dressed Corn (lbs.).	56·7	56·5	57·5	57·2	57·7	57·5	55·7		56·97
Per Cent. Dry Substance in Corn (at 212°)	80·0	81·2	81·1	80·9	81·7	80·9	80·6		80 91
Per Cent. Ash in Dry Substance ..	1·89	1·93	1·88	1·98	1·92	1·91	1·92		1·92
Constituents of Ash:—									
Phosphoric Acid	47·08	48·69	45·69	47·81	51·56	50·26	51·34	50·01	49·05
Phosphate of Iron	1·97	2·31	3·66	4 58	1·21	1·07	·80	1·20	2·10
Potass	25·16	28·53	29·06	28·87	31·75	32·27	30·20	30·47	29·54
Soda	8·01	·00	6·19	5·01	·00	·00	·68	·00	2·49
Magnesia	11·06	11·58	9·57	8·98	10·14	10·00	10·65	9·96	10·24
Lime	3·66	3 57	3·39	2 02	3·20	3·36	3·06	3·16	3·18
Chlorine	·00	·20	·00	·00	Trace	Trace	·40	·23	·10
Silica, Sand, and Charcoal	3·29	3·39	1·45	1·68	2·36	2 21	2·61	3·40	2·55
Totals	100·23	98·27	99·01	98 95	100·22	99·17	99·74	98·43	99·25

TABLE VI.

Analyses of Wheat-Grain Ash.

Harvest, 1846.

Plot Numbers	2	3	1	8 B	4	11 B	
Manuring, per acre	Farm-yard Manure, 14 tons.	Unmanured.	Bone-ash, 224 lbs.	Bone-ash, 224 lbs. Sulphate and Muriate Ammonia, each 112 lbs.	Bone-ash, 224 lbs. Hydrochloric Acid 224 lbs. Sulphate Ammonia, 224 lbs.	Bone-ash, 224 lbs. Sulphuric Acid, 224 lbs. Sulphate and Muriate Ammonia, each 112 lbs.	Means.
Character of the produce:—							
Per Cent. Corn in Total Produce ..	42·7	44·4	43·6	43·6	42·6	43·1	43·3
Weight per bushel of Dressed Corn (lbs.) .	63·0	63·7	62·6	63·6	63·5	63·2	63·3
Per Cent. Dry Substance in Corn (at 212°) .	84·1	84·0	83·3	84·5	84·8	83·9	84·1
Per Cent. Ash in Dry Substance ..	2·07	2·03	2·04	1·91	1·99	1·91	1·99
Constituents of Ash:—							
Phosphoric Acid	50·01	49·89	50·62	49·47	48·73	50·08	49·80
Phosphate of Iron	1·65	1·66	3·10	2·52	2·62	3·06	2·43
Potass	30·03	30·60	27·93	29·58	31·00	29·18	29·72
Soda	·35	·25	·00	·00	·00	·00	·10
Magnesia	11·03	10·97	10·79	11·13	10·43	10·34	10·78
Lime	2·98*	2·89*	4·04	4·63	4·31	4·22	3·84
Chlorine	·12	·09	·30	·34	Traces	·17	·17
Silica, Sand, and Charcoal	1·88	2·17	2·18	2·54	2·62	3·00	2·40
Totals	98·05	98·52	98·96	100·21	99·71	100·05	99·24

* It would seem probable that in these two cases the Lime is given too low; but as the analyst, Mr. Ashford, is dead, no reference can be made, and we have unfortunately not had time to repeat the analyses prior to publication, as we had intended.

It is at once seen, that this ash may be reckoned to contain neither sulphuric acid, carbonic acid, nor chlorine. The latter at least occurred only occasionally, and then in such small quantities, as to lead us to the supposition that its presence is accidental, or at any rate not essential, in the ash of a perfectly-ripened grain. From the frequent absence of soda again, and from the uncertainty in its determinations as above alluded to, we are led to look at it as an equally unessential ingredient in the grain-ash of perfectly ripened wheat. Excluding then the chlorine, the soda, the iron of the phosphate of iron, and that portion of the matter collected as insoluble, which may have been soluble silica—the whole of these, on the average, amounting to a very few per cent.—the ash of wheat-grain is seen to consist essentially of *phosphates only;* the bases being potash, magnesia, and lime. The potash amounts to nearly one-third of the whole ash; the magnesia to rather more than one-third of the potash; and the lime to about one-third of the magnesia.

If we now compare with one another the analyses of the eight different ashes in 1844, those of the seven in 1845, or of the six in 1846, having regard to the manures by which the crops were grown, it is impossible to say that these have had any direct and well-defined influence upon the composition of the ash of the grain. Thus we find, looking at the Table for 1844, that several of the plots manured with superphosphate of lime, yield a grain-ash having no higher percentage of phosphoric acid than that of the unmanured plot. Again, where potash is added (plots 15, 16, and 18), the percentage of it in the ash is not greater than the average of the cases where it was not employed. And again, in the only case where soda was employed (plot 16), there is none of it found in the ash; nor, lastly, is the percentage of magnesia obviously increased by the use of it in manure. A similar detailed consideration of the composition of the ashes of the seasons of 1845 and 1846, would, as already intimated, lead to a similar conclusion. In fact, the variations in the composition of the ash of this supposed ripened product, according to the manure by which it is grown, seem to be scarcely beyond the limits of error in the manipulation of the analysis; though, one case at least of the duplicate analysis of the same ash—namely, that of No. 9, 1844—indicates the range of variation from this cause to have been but small; in the other, (No. 17, 1845) it was somewhat greater.

Although the accuracy of the analyses may not be such as to

show the difference in composition, if any, dependent on *manure,* yet it is found to be quite adequate to indicate the marked differences in the *degree of development and maturation* of the grains, dependent upon *season.* Before calling attention to the figures illustrating this point, it should be remarked that the season of 1845 was the worst but one, and that of 1846 nearly the best, for ripening the grain, during the thirteen years of our continuous growth of wheat. And we shall find, consistently with this, and with the conclusions arrived at in connection with Tables I and III, that the variation in the composition of the ash is, comparing one year with another, much the greatest in the produce of the bad ripening season 1845, and much the least in the good ripening season 1846. This point, and some others, are illustrated in the following Summary Table, No. VII.

TABLE VII.

Composition of Wheat-Grain Ash.

	Variation in per Cent. in each Season.			Mean for each Season.			Means according to Manuring.			General Means.	
	1844 9 Cases.	1845 8 Cases.	1846 6 Cases.	1844 9 Cases.	1845 8 Cases.	1846 6 Cases.	Unmanured (3 years).	Farm-yard Manure (3 years).	Other Manures (3 years), 17 Cases.	23 Cases, Rothamsted.	26 Cases, Mr. Way.
Characters of the produce:—											
Per Cent. Corn in Total Produce ..	..	..	..	46·2	34·1	43·3	41·4	40·8	41·3	41·2	
Weight per bushel of Dressed Corn (lbs.) .	..	..	..	60·4	57·0	63·3	59·6	59·6	60·1	60·0	
Per Cent. Dry Substance in Corn (at 212°)	..	..	..	82 6	80·9	84·1	82·3	82·3	82·5	82·4	
Per Cent. Ash in Dry Substance ..	..	..	..	2·05	1·92	1·98	2·04	2 01	1·97	1·99	1·69
Composition of Ash:—											
Phosphoric Acid	3·30	5·87	1·89	50·16	49·05	49·80	49·81	48·41	49·88	49·68	45·01
Phosphate of Iron	·90	3·87	1·45	2·54	2·10	2·43	2·14	2·06	2·45	2·36	0·82*
Potass	2·82	7.11	3·07	28·93	29·54	29·72	29·78	28·03	29·50	29·35	31·44
Soda	2·10	8·01	·35	·57	2·49	·10	·08	3·04	·95	1·12	2·71
Magnesia	1 74	2·60	·79	11·07	10·24	10·78	11·20	11·31	10·51	10·70	12·36
Lime	1·06	1·64	1·74	3·30	3·18	3·84	3·15	3·47	3·43	3·40	3·52
Sulphuric Acid	..	..	..	..		..	..	..	..	..	0·34
Carbonic Acid	..	..	..	..		..	..	..	..	..	0·02
Chlorine	..	..	..	·13	·10	·17	·14	·04	·14	·13	·13
Silica, Sand, and Charcoal	..	..	..	2·45	2·55	2·40	2 76	2·60	2·41	2·47	3·67†
Totals	..	..	..	99·15	99·25	99·24	99·06	98·96	99·27	99·21	100·03

* Peroxide of iron.

† Mr. Way gives this as soluble silica, exclusive of the sand and charcoal included with it in our own analyses.

Looking at the first Division of this Table VII, it is seen that in the item of *phosphoric acid,* the variation in the percentage among the several cases in each year, is the greatest in 1845, and the least in 1846; in the *phosphate of iron,* it is the greatest in 1845; in the *potash,* it is the greatest in 1845, much less and about equal, in 1844 and 1846; in the *soda,* it is much the greatest in 1845, and much the least in 1846; in the *magnesia,* it is again far the greatest in 1845, and it is the least in 1846. In the case of the *lime,* we have an exception to this general indication, dependent on the two low amounts of it given for Nos. 2 and 3, 1846; but if these are really in error in the direction suggested at the foot of Table VI, the indication would be the same as for the other constituents. We have then in the circumstances of the seasons, and in the comparative characters of the produce coincident with these variations, the evidence that for one and the same description of grain, in a perfectly matured condition, the composition of the ash will be, within certain narrow limits, constant.

So far as the constituents of the ash of the entire grain of wheat is concerned, we have only further to call attention to the three other Divisions of this Summary Table No. VII. In these are shown, side by side:—

In the second Division of the Table, the mean composition of the ashes for each of the three separate years;

In the third Division, the mean composition for the three years together: (*a*) of the grain-ash from the unmanured plot—(*b*) of that from the farm-yard manured-plot—(*c*) of the grain-ashes from all the other manures during the three years, including 17 cases; and

In the fourth and last Division, the mean composition of all our own wheat grain-ashes analyzed, 23 in number, by the side of the mean of 26 analyses of the grain-ashes of wheat, of different descriptions or grown in different localities, published by Mr. Way.

We will go into very little detail discussions of these mean results, as the points they illustrate have most of them already been alluded to. We may first remark, as a point to which we shall recur further on, that the mean percentage of *lime,* is the least in the bad year 1845, and the greatest in the good year 1846. Again, it is greater in the average from the manured plots, than in that from the unmanured. We may perhaps here anticipate by saying, that this is at any rate consistent with what we shall

afterwards have to record, namely, that the ash of the finer flour —of which there is a greater proportion in the grain of the seasons of best maturation—contains more lime than that of the coarser and more branny portions of the grain.

Lastly, in reference to this Summary Table, we would call attention to the mean composition of wheat grain-ash yielded by the 26 analyses given by Mr. Way, by the side of that of the 23 specimens grown at Rothamsted. Mr. Way's analyses, equally with our own, show that wheat grain-ash essentially consists of phosphates of potash, magnesia, and lime. He, however, if we exclude silica, gives higher percentages of base, and a lower one of acid, than our own analyses indicate. Mr. Way's average amount of phosphoric acid is indeed nearly 5 per cent. less in the ash than ours. His series, however, included many descriptions of wheat, and our own only one—the Old Red Lammas. In several of his cases, too, we observe that the percentage of this acid very closely approximates to our own average.

We have now given a summary view of some points of the composition of the entire wheat-grain, and of its ash, as affected by varying season, and various manuring. We next turn to an equally summary statement, of a large number of experiments made in reference to the *yield*, and *composition*, of the various products separated in the milling process. The grains operated upon with this view, were of the same description of wheat, but grown experimentally in different seasons, and under different conditions of manuring.

There have been many observations recorded as to the percentage of flour obtained in practice from 100 parts of grain, and in a subsequent Table some of these will be adduced. We are also indebted to M. Boussingault for the determination of the flour and of the bran, yielded by 24 different descriptions of wheat, all grown side by side in the Jardin des Plantes at Paris. His method was to powder the grains in a mortar, and separate the flour and bran by means of a silken sieve. Results of this kind can, perhaps, scarcely be compared with those of the ordinary mill. The differences exhibited between the different specimens were indeed very great; but the comparisons afforded within the series itself are interesting and very curious.

In our own experiments, the so-called *Colonist's steel hand-mill* was first had recourse to; as it was thought that by its use, rather

than that of an ordinary flour-mill, much smaller quantities of grain might be submitted to experiment, and that uniformity of working would also be more within our control. It was soon found, however, that in all cases the grain was, in this steel-mill, rather cut up than crushed and rubbed down, as between ordinary mill-stones. It was also found, that the action in this respect varied considerably according to the speed of the operator, and to the precise set of the mill, which required to be varied according to the character of the grain. From these causes a statement of the *amount of the yield*, of the various products obtained from the steel hand-mill, would be of little value. Though further on we shall have to call attention to some interesting points connected with the comparative composition of the several products of the grains mechanically separated in this way.

We next determined to submit a series of the experimentally grown grains, to careful, and as far as possible, uniform treatment between the stones, and in the dressing apparatus, of an ordinary flour-mill. The mill in question was worked by water-power. From 125 to 250 lbs. of the several grains were submitted to the experiment; the whole of the apparatus being carefully cleared of the products of one specimen before another was commenced upon. The weights and samples of the *"meals"* as furnished by the stones, and of the several products separated in the dressing-machine, were taken under our own personal superintendence. Even here, and although every possible precaution was taken, considerable irregularities in the action of the apparatus were manifest, depending partly on the varying characters of the grain. Indeed it was clear, that to obtain results as to comparative yield of flour, strictly referable to the practical qualities of the respective grains, it would be necessary to operate on much larger quantities of each than those even now taken, in order that the miller might so re-adjust the set of his stones, as the work proceeded, according to the character of the grain and of the meal which it afforded, as to get from each its largest yield, as he would do in working upon considerable quantities. In all, twenty-eight lots of grain were operated upon in this way; and although, as above implied, and as will be pointed out further on, the results might in some points have been somewhat different with larger quantities, yet the miller, after a careful examination of all the products, decided that their general bearings were to be fully trusted.

In some cases the meal obtained from the stones was separated

in the dressing apparatus into nine products, and in others the products of the first three wires were taken together, constituting the bulk of the *fine* flour obtainable, and amounting to only about 70 per cent. of the grain. In practice, however, the fourth product of the dressing machine, "*Tails,*" is generally redressed, and the fifth, "*Fine Sharps*" or "*Middlings,*" reground and redressed, together raising the amount of good bread-flour to about 80 per cent., or sometimes more. The sixth product is called "*Coarse Sharps;*" the seventh, "*Fine Pollard;*" the eighth, "*Coarse Pollard;*" and the ninth, "*Long Bran.*" It should be stated, however, that mills vary very much in the arrangement of their dressing machines in different localities, and even in the same locality; so that the exact division of the products here given, will not apply invariably.

In Table VIII are given—

1st. In the upper division of the Table, the percentage yield in 100 meal, of each of the mill products, 7 or 9, as the case may be; each figure being the mean of several experiments.

2nd. (In the middle division of the Table)—The mean per cent. of dry substance (at 212°), in each flour, bran, &c. And,

3rd. The mean per cent. of mineral matter (ash), in each of the same mill products.

As will be seen, seven of the specimens were grown in 1846, nineteen in 1847, and two in 1848; and in order to give some idea of the general character of the produce yielding the results in each of the separate columns, there is given at the head the mean bushels per acre, the mean weight per bushel, and the mean per cent. of corn in total produce, of the specimens to which the column refers.

TABLE VIII.

Showing the yield of the different Mill Products from 100 of Grain; and their Per-centages of Dry Substance and Mineral Matter.

MEAN RESULTS.

	Products of Wires 1, 2, and 3.					Means of all in each year.			Mean of all in the three years; 28 cases.	Distribution of Ash in the several Products of 100 Meal.
	1846		1847		1848	1846, 7 cases.	1847, 19 cases.	1848, 2 cases.		
	Taken separately	Taken together.	Taken separately.	Taken together.	Taken separately.					
General Characters of Produce:—	Mean of 3 cases.	Mean of 4 cases.	Mean of 4 cases.	Mean of 15 cases.	Mean of 2 cases.					
Mean bushels per acre	26¼	29¼	25¼	33	31½	28	31⅓	31½	30½	
Mean weight per bushel (lbs.)...	63·5	63·3	61·7	62·2	59·1	63·4	62·1	59·1	62·2	
Mean p. c. corn in total produce.	43·5	42·7	35·9	36·0	37·1	43·0	38·0	37·1	37·8	
Yield of Flour, Bran, &c., in 100 Meal.										
1. Wire 1	44·0	...	35·7	...	47·4	44·0	35·7	47·4	41·1	
2. Wire 2	17·9	...	16·4	...	23·9	17·9	16·4	23·9	18·6	
3. Wire 3	8·7	...	13·3	...	2·0	8·7	13·3	2·0	9·2	
Products 1, 2, and 3, together.	70·6	68·3	65·4	71·5	73·3	69·3	70·2	73·3	70·2	
4. Tails	4·8	5·1	7·7	5·3	2·1	4·9	5·8	2·1	5·3	
5. Fine Sharps or Middlings ...	8·7	11·4	10·3	8·3	4·5	10·2	8·7	4·5	8·8	
6. Coarse Sharps	3·1	3·8	3·8	3·2	3·8	3·5	3·3	3·6	3·4	
7. Fine Pollard	1·8	5·5	1·9	1·8	2·6	3·9	1·8	2·6	2·4	
8. Coarse Pollard	6·8	2·7	7·4	7·1	7·9	4·4	7·2	7·9	6·5	
9. Long Bran	4·3	2·9	3·2	2·3	5·9	3·5	2·5	5·9	3·0	
Per Cent. Dry Substance (at 212° F.) in each Flour, Bran, &c.										
1. Wire 1	84·4	...	83·8	...	85·4	84·4	83·8	85·4	84·3	
2. Wire 2	84·5	...	83·7	...	85·2	84·5	83·7	85·2	84·3	
3. Wire 3	84·5	...	83·9	...	85·2	84·6	83·9	85·2	84·4	
Products 1, 2, and 3 together.	...	84·7	...	83·8	...	84·6	83·8	85·3	84·1	
4. Tails	84·4	85·2	84·3	85·2	85·5	84·8	85·0	85·5	85·0	
5. Fine Sharps or Middlings ...	83·1	84·9	84·0	84·7	85·3	84·1	84·5	85·3	84·5	
6. Coarse Sharps	86·5	85·1	82·2	86·2	85·4	85·7	85·3	85·4	85·4	
7. Fine Pollard	87·3	85·8	82·2	85·5	85·7	86·4	84·8	85·7	85·3	
8. Coarse Pollard	86·4	84·9	82·8	86·0	88·2	85·5	85·3	88·2	85·4	
9. Long Bran	88·3	85·5	83·1	85·6	85·7	85·8	85·1	85·7	85·3	
Per Cent. Mineral Matter (Ash) in each Flour, Bran, &c.										
1. Wire 1	0·70	...	0·88	...	0·70	0·70	0·68	0·70	0·69	·284
2. Wire 2	0·71	...	0·71	...	0·73	0·71	0·71	0·73	0·71	·132
3. Wire 3	0·75	...	0·74	...	0·87	0·75	0·74	0·87	0·73	·067
Products 1, 2, and 3, together.	...	0·71	...	0·70	...	0·71	0·70	0·77	0·71	·483
4. Tails	0·92	1·01	0·93	1·08	1·04	0·97	1·05	1·04	1·03	·054
5. Fine Sharps or Middlings ...	1·82	1·88	1·54	2·43	1·88	1·85	2·24	1·88	2·12	·186
6. Coarse Sharps	3·77	4·35	3·74	4·43	3·54	4·10	4·28	3·54	4·18	·142
7. Fine Pollard	5·86	6·01	5·45	5·65	5·03	5·94	5·81	5·03	5·65	·138
8. Coarse Pollard	6·91	6·85	8·41	6·39	5·84	6·88	6·39	5·84	6·47	·420
9. Long Bran	7·63	7·27	6·67	7·19	6·34	7·42	7·08	6·34	7·11	·213
Total	...	...	...	...	...	...	...	...	...	1·634

After the remarks already made, little need be said in detail regarding the comparative yield of the various products by 100 parts of the different meals. It was decided by the miller, that pretty uniformly there was too much flour left in the fourth, but particularly in the fifth product; and this, as an inspection of the Table will show, was obviated in the later experiments, namely, those on the grain of the harvest 1848. So far, then, the variation of the result is more due to the management of the miller, than to the intrinsic character of the grain.

It is more interesting to observe, that a very careful examination of all the products led to the conclusion, that the grains grown by the more nitrogenous manuring, and consequently in the larger crops, *provided they were well developed and matured,** allowed a better separation of the flour, and less cutting up and intermixture of branny particles with it; and hence, yielded a cleaner bran than the grain of the poorer crops. This was not the case, however, unless the highly-manured crops were at the same time well developed. It is consistent with this character of the grain of the more highly-manured crops, that the produce of the heavier and richer wheat-lands is generally admitted to yield a larger proportion of flour. The fact that the grain of richly-manured crops is frequently coarse, and not the good miller's sample, arises from the circumstance, not of the direct effect of rich manuring in depreciating the quality of the grain, but because the larger crops are more subject to injury due to climatic circumstances, and are consequently frequently less favourably developed and matured.

It will be observed, that the amount of long bran is always more than 2, and in the year of badly-ripened grain (1848), it is nearly 6 per cent. of the total meal. This ninth product, together with the three or four immediately before it in the list, yield us nearly 20 per cent. of the total meal, of such a branny character as seldom to be used for human food. Some of the more recent experimenters, MM. Millon and Peligot for example, have concluded that the amount of actual woody fibre in wheat-grain is seldom more than from 2 to 3 per cent. On this supposition, the nearly 20 per cent. of the grain generally not applied directly as human food, would contain but a small proportion of necessarily indigestible woody matter; and it would appear that there was very great room for improvement in the modes of preparation of the grain, if

* It would appear that, in a good ripening season, this condition is best attained when the crop is cut before the grain is perfectly ripe.

it were desirable to separate as human food in the first instance, a larger proportion of its nutritious matters. M. Poggiale, on the other hand, maintains that the quantity of woody fibre refractory to the digestive organs, though not to chemical agents out of the body, is really very considerable.* But, of some points of the composition of the various products, we shall have to speak more in detail presently.

In the second or middle division of Table VIII, we have the average percentage of dry matter in the different products. In reference to these results it may be noticed, that, as might be expected, the percentage of dry matter is rather higher in the mill products, than it was in the entire grains which yielded them. This is particularly the case in regard to the two specimens of the harvest 1848, the mill products of which give, on the average, a higher per cent. of dry matter than the samples of either of the other two years, although the dry matter of the entire grain of that season (1848), was very low. The differences are therefore obviously more due to the circumstances of preservation and after-treatment, than to distinctions in the character of the respective grains. The only other remark which need be made regarding the varying percentages of dry matter, is, that the branny, or more external portions of the grain, have pretty uniformly a higher percentage of dry matter than the more farinal internal portions.

The widely differing percentages of *mineral matter* in the several mill-products of the same grain, and the variations in this respect, even between the corresponding products in the different specimens, in the same, or in different seasons, are both more striking, and of greater interest.

It is seen, that we have about ten times as high a percentage of ash in the ninth product, or bran, as in the first three, or purer flours. The percentage increases rapidly from the fourth to the ninth—that is to say, the greater the proportion of branny particles. A careful examination of the more detailed Tables also showed, that the variations in the percentage of mineral matter in the corresponding products of different specimens of grain, had a direct relation to the percentage, or relative position of the respective products, in the 100 of meal; in other words, to the

* Since the above was written, a very favourable report has appeared in the "Comptes Rendus" (January 12, 1857), by MM. Dumas, Pelouze, Payen, Peligot, and Chevreul —the Commission appointed by the Academy of Sciences, to inquire into the matter —on a new process of M. Mège Mouriès, which claims to yield a perfectly white, wholesome, and agreeable bread, employing 86—88 per cent. of the entire grain.

proportions of flour or of bran which they respectively contained. Although, however, the *percentage* of mineral matter is so very much greater in those portions of the grain which are not generally used in the first instance as human food, yet, an inspection of the last column of the Table, showing the *distribution* of the mineral matter in the several products of 100 of meal, according to the amount of each of these, will show that, even in our first three products, we have nearly one-third of the whole mineral matter of the grain; and adding to these a certain portion of that in the fourth and fifth products, which frequently contribute to the bread-flour, we shall have more than one-third of it in the currently edible portion of the grain. Further information as to the composition of the respective mill-products, and of their ashes, will be found in Tables IX, X, XI, and XII.

In Table IX are given the individual nitrogen determinations in each of the several mill-products; those in the first three columns being by one experimenter, and those in the fourth column by another. In Table X is given a collective view of the composition of the same products, in regard to some other constituents, as far as they have been determined; including also the mean results of Table IX.

TABLE IX.

Determinations of Nitrogen per Cent. in Mill Products of Wheat-Grain.

HARVEST 1846; GROUND 1848.

Description of Mill Products.	In natural state of dryness.				
	Experiments.				Mean.
	1.	2.	3.	4.	
1. Wire 1	1·59	1·69	1·62	..	1·63
2. „ 2	1·64	1·73	1·69	..	1·69
3. „ 3	1·77	1·78	1·79	..	1·78
4. Tails	1·88	1·86	1·84	..	1·86
5. Fine Sharps, or Middlings ..	2·20	2·20	2·22	2·22	2·21
6. Coarse Sharps	2·58	2·52	2·59	2·62	2·58
7. Fine Pollard	2·43	3·37	2·48	2·48	2·44
8. Coarse Pollard	2·41	2·32	2·47	2·46	2·42
9. Long Bran	2·37	2·37*	..	2·42	2·39

* By a third experimenter.

TABLE X.

Composition of Mill-products of Wheat Grain.

HARVEST 1846; GROUND 1848.

Description of Mill Products.	Flours, &c. from 100 Grain.	In 100 of each Product.			In 100 each Ash.		Distribution of Constituents in Mill Products of 100 Grain.			
		Dry Substance (at 212° F.)	Mineral Matter (Ash).	Nitrogen.	Insoluble in Acid.	Phosphoric Acid.	Mineral Matter.	Nitrogen.	In the Ash. Insoluble in Acid.	In the Ash. Phosphoric Acid.
1. Wire 1	51·2	85·5	0·71	1·63	6·04	44·3	0·36	0·83	0·022	0·161
2. ,, 2	24·8	85·6	0·74	1·69	5·83	45·5	0·18	0·42	0·010	0·083
3. ,, 3	1·7	85·0	0·82	1·78	5·74	48·1	0·01	0·03	0·000	0·007
4. Tails	1·6	85·2	1·04	1·86	2·18	48·4	0·02	0·03	0·000	0·008
5. Fine Sharps, or Middlings ..	3·3	85·5	2·19	2·21	3·04	51·3	0·07	0·07	0·002	0·037
6. Coarse Sharps ..	3·3	86·1	3·93	2·58	3·84	49·6	0·13	0·08	0·005	0·064
7. Fine Pollard ..	1·8	86·5	5·46	2·44	0·84	52·3	0·10	0·04	0·001	0·051
8. Coarse Pollard ..	6·7	86·1	6·56	2·42	0·56	55·2	0·44	0·16	0·002	0·242
9. Long Bran ..	5·0	86·4	7·14	2·40	0·60	54·8	0·36	0·12	0·002	0·195
Totals ..	99·4	..	..	..	..	..	1·67	1·78	0·044	0·850

The grain to which Tables IX and X refer, was an equal mixture of the produce from four different plots, very variously manured, and grown in the season 1845-6; the harvest of which yielded one of the best-matured grains throughout our series of field experiments. The wheat in question was, however, not ground until 1848; and we have in the percentage-yield of the respective products, confirmation of the general opinion, that other things being equal, old wheat yields up its flour better than new. Thus, whilst in the average of the cases already recorded, we have little more than 70 per cent. of flour through the first three wires, we have from this old wheat 77¾ per cent. The products 4 and 5, from which a further yield of bread-flour is obtained, were correspondingly small; but Nos. 8 and 9 were, on the other hand, somewhat large.

The particulars given in Table X are the percentages of *Dry Matter,* of *Ash,* and of *Nitrogen,* in the respective mill-products of this mixed grain. There are also given the percentages of *Matter insoluble in Acid,* and of *phosphoric acid* in each of the nine ashes; and in the last four columns we have the *distribution* of the total mineral matter, of the nitrogen, and also of the insoluble matter, and phosphoric acid of the ash, in each of the nine products, according to the proportion of the latter in 100 of the grain or meal.

The percentage of *Dry Matter* in the several products from this old grain is, as would be expected, somewhat higher than the average from the grains of the same year which had not been so long stored. As before, the percentage of Dry Matter shows a tendency to increase as we proceed to the outer portions of the grain. The percentages of ash also show the same relations as already pointed out.

Referring to the column of the percentage of nitrogen in each of the nine separated products, we find that it is lowest in the products at the head of the dressing machine—that is, in the flours; and it is half as high again in the more branny portions. It is seen, however, to be the highest of all in the product No. 6; and somewhat lower in the coarser brans. It may be remarked, that the indications of the figures in this respect are at any rate consistent with such observations as have been recorded regarding the structural composition of wheat-grain; it being stated that the greatest concentration of nitrogenous compounds is immediately below the pericarp itself; and we should expect that the

longer bran would have less of the more internal matters adherent to it.

The higher percentage of nitrogen in bran than in fine flour, has frequently led to the recommendation of the coarser breads as more nutritious than the finer. We have already seen that the more branny portions of the grain, also contain a much larger percentage of mineral matter. And further, it is in the bran that the largest proportion of fatty matter—the non-nitrogenous substance of highest respiratory capacity which the wheat contains—is found. It is, however, we think, very questionable whether, upon such data alone, a valid opinion can be formed of the comparative values as food, of bread made from the finer or coarser flours from one and the same grain. The published evidence at command leads to the conclusion, that of the nitrogenous constituents of bran, a much larger proportion is soluble in water, than of those in the finer flours. That is to say, there is in the bran, probably, a larger proportion of the more universal vegetable compound, albumen, and less of those more special to the grain of wheat; and hence we may perhaps conclude, that it exists in a less elaborated, and probably, therefore, less assimilable condition.* It is stated, on the other hand, by Poggiale, that a large proportion of the insoluble nitrogenous constituents of bran, occurs in a form only in an inferior degree digestible. Again, it is an indisputable fact, that branny particles, when admitted into the flour in the degree of imperfect division in which our ordinary milling processes leave them, very considerably increase the peristaltic action; and hence the alimentary canal is cleared much more rapidly of its contents. It is also well known, that the poorer classes almost invariably prefer the whiter bread; and among some of them who work the hardest, and who consequently would soonest appreciate a difference in nutritive quality (navvies for example), it is distinctly stated, that their preference for the whiter bread is founded on the fact, that the browner passes through them too rapidly; consequently, before their systems have extracted from it as much nutritious matter as it ought to yield them.

* According to M. Mège Mouriès, before referred to, a portion of the soluble nitrogenous matter of bran exists as a peculiar body, *Cerealine*, which when dissolved up from bran in water at a given temperature, effects the solution of the adherent starch also. His process of extracting from the bran an additional amount of the bread-material which the grain contains, consists in fermenting, after the addition of some glucose, an infusion of the finer brans, straining off the woody matter, and using the fluid in making up the dough with the finer flour.

It is freely granted, that much useful nutritious matter is, in the first instance, lost as human food, in the abandonment of 15 to 20 per cent. of our wheat-grain to the lower animals. It should be remembered, however, that the amount of food so applied, is by no means entirely wasted. And further, we think it more than doubtful, even admitting that an increased proportion of mineral and nitrogenous constituents would be an advantage, whether, unless the branny particles could be either excluded, or so reduced as to prevent the clearing action above alluded to, more nutriment would not be lost to the system by this action, than would be gained by the introduction into the body coincidentally with it, of a larger actual amount of supposed nutritious matters. In fact, all experience tends to show, that the *state*, as well as the chemical composition of our food, must be considered; in other words, that its digestibility, and aptitude for assimilation, are not less important qualities, than its ultimate composition. Observation also tends to show, that elaboration, or maturation, have their influence in determining the digestibility or the assimilability of our food—both the vegetable and animal. But to this point we shall refer again presently.

Returning to the experimental results in Table X, the next point of remark is as to the amount of matter *insoluble in acid*, in the ash of the respective mill-products. It is seen, that the percentage of such matter is very much greater—indeed in this particular case, ten times greater—in the ash of the finest flour, than in that of the coarsest bran. It was at first thought that this must be an error. Some repetitions were therefore made, and the products of the steel-hand-mill were also examined; when it was found that the result in question was fully confirmed. It would be interesting to examine the series, to determine what proportion of this insoluble matter is really proper mineral constituent of the respective products, and how much adventitious merely. On consideration, it will however be clear, that the process of dressing the meal would tend to shake and clean the bran, from all adherent matters; which, if silicious, as well as the particles arising from the abrasion of the mill-stones, would naturally be found among the heavier products at the head of the machine. That is to say, they would be found in larger proportion in the flour, whilst the bran, by the mechanical methods of its separation, would be almost entirely freed from them. According to published analyses, it would appear, however, that *silica*, as

distinguished from merely insoluble sandy matter, does exist to a considerable, though variable extent, in the ash of entire wheat-grain. And from the results now given, it may perhaps be concluded, that this constituent found to exist so constantly in some animal substances, does really occur in larger amount in those portions of wheat-grain which are best adapted as food?

Phosphoric acid, on the other hand, is seen to be in smallest proportion in the ash of the flour at the head of the dressing machine; and the percentage pretty gradually augments as we proceed from the finer to the coarser and more branny portions, the ash of the latter being far the richest in this essential acid.*

It may further be remarked in reference to the varying composition of the ash of the different mill-products, that in several series we have found the *magnesia* greatly to increase as we proceed from that of the finer to that of the coarser products. The percentage of *lime* is, on the other hand, greatest in the ash of the flours, and less in that of the brans. This latter point is consistent with a tendency discernible, to an increase in the percentage of lime in the ash of those grains most matured in one and the same season, or in the ash of the grains grown in a season of higher maturing character. We may further conclude, from the great increase in the percentages both of the phosphoric acid, and of the magnesia, as we proceed from the ash of the flours to that of the brans, and also from the very slight compensation from the decrease in that of the lime (the total amount of lime being relatively small), that the chief complementary constituent of wheat-grain ash—namely, *potash*—will occur in larger proportion in the ash of the flours than in that of the brans; hence, its larger amount will be coincident with the larger amount of silica.

In the last Division of Table X is shown the *distribution* in the respective products from 100 of grain, or its meal—of the nitrogen, of the total mineral matter, and of the insoluble substance and phosphoric acid of the latter—which the entire grain contained.

It will be seen, that notwithstanding the percentage of nitrogen is so much greater in the branny products, yet owing to the smaller amount of these, by far the larger proportion of the total nitrogen of the grain is accumulated in the flours. In fact, in the case

* Probably a portion of the phosphoric acid existing in wheat-grain-ash is due to the oxidation, during incineration, of phosphorus, found by Professor Voelcker to exist in such large amount, associated with the nitrogenous bodies. See also Professor H. Rose on this subject—Poggendorff's Annalen, vol. lxxvi. p. 305.

before us about three-fourths of the nitrogen would be accumulated in those of the products which would be ordinarily used for bread, or for human food in other forms. On the other hand, only about two-fifths of the total mineral matter would be found with this three-fourths of the nitrogen. Of the *phosphoric acid* again, the larger amount is distributed in the branny portions; only about one-third of it being obtained in the bread flours. At the foot of these columns of the distribution of the constituents, the percentage in the entire grain or meal of the items as determined by analysis in each separate product, is given by the addition of these items so obtained; and the percentage so calculated agrees very closely with that which the analysis of the entire wheat-grain or its ash would indicate. Thus we may mention, that according to the sum of the phosphoric acid distributed in the different products, we have 50·7 per cent. of it in the ash of 100 of grain or meal; whilst the average percentage obtained in the analyses of the six ashes of the produce of the same season, was 49·8, an approximation sufficiently near to give some confidence, at least in the relative accuracy of the numerous analytical results involved in such an estimate.

Before leaving the question of the comparative chemical composition of the different products obtained by means of mechanical separation from wheat-grain, attention may be called to some results of this kind, in connection with the products of the Colonial steel-hand-mill, which was first employed in these experiments. As will be seen, the results now to be recorded agree in general tendency with those already given; yet they have some special and curious points of interest. The individual nitrogen determinations are given in Table XI, and the collected results of the examination of the various products in Table XII.

TABLE XI.

Nitrogen per Cent. in the Products of Wheat-Grain, from the Colonial Steel-hand-mill.

(In natural State of Dryness.)

Products from	Wheat-Grain, Harvest 1846.					
	Unmanured.			Manured.		
	Experiments.		Mean.	Experiments.		Mean.
	1.	2.		1.	2.	
First Grinding :—						
Wire 1	1·94	1·89	1·91	1·59	1·60	1·59
Wire 2	1·57	1·59	1·58	1·44	1·49	1·47
Second Grinding :—						
Wire 1	1·89	1·90	1·89	1·60	1·61	1·60
Wire 2	1·73	1·78	1·76	1·53	1·65	1·59
Wire 3	1·78	1·76	1·77	1·58	1·49	1·54
Bran	2·07	2·09	2·08	1·69	1·79	1·74

TABLE XII.

Composition of the Products of Wheat-Grain from the Colonial Steel-hand-mill.

Products from	Wheat-Grain, Harvest 1846.								
	Unmanured.					Manured.			Mean of 5.
	In 100 of each Product.			In 100 of each Ash.		In 100 of each Product.			Ash in 100 of each Product.
	Dry Substance (at 212° F.).	Mineral Matter (Ash).	Nitrogen.	Phosphoric Acid.	Magnesia.	Dry Substance (at 212° F.).	Mineral Matter (Ash).	Nitrogen.	
First Grinding :—									
Wire 1	84·0	0·78	1·91	45·3	6·95	84·4	0·78	1·59	0·75
Wire 2	85·2	0·77	1·58	45·0	6·25	83·9	0·79	1·47	0·78
Second Grinding :—									
Wire 1	85·0	1·23	1·89	49·7	9·04	84·8	1·02	1·60	1·22
Wire 2	85·0	1·17	1·76	52·0	9·09	85·3	1·07	1·59	1·24
Wire 3	85·4	1·83	1·77	51·4	11·20	85·4	1·70	1·54	2·01
Bran	86·5	5·76	2·08	53·0	13·57	87·3	5·64	1·75	5·70

It should be mentioned in reference to the working of the steel-hand-mill, that on passing the grain through the apparatus, four products were first obtained, namely, two fine flours, thirds, and bran; the last two products of the first grinding being mixed together, were passed through the mill a second time, and four products again separated. After this explanation, the designation of the products in Tables XI and XII will be sufficiently intelligible.

With the information derived from the previously recorded results, a glance at the percentages of ash in the several products of the different grains, as given in Table XII, will show that the so-called "bran" here obtained, retained more flour than from the ordinary flour-mill. In fact it was obviously pretty nearly equivalent to the 9th, 8th, 7th, 6th, and part of the 5th products of the ordinary mill taken together. The five flours, on the other hand, but especially the three from the second grinding, obviously contained rather more branny particles than the ordinary bread-flours of the other series of the experiments. Such, indeed, was the obvious character from an inspection of the various products.

Consistently with the character of the products thus defined, the variations in their percentages of nitrogen are, upon the whole, much less than in the former series; but such as they are they are very curious. Thus in both instances, though in a less marked degree in the manured than in the unmanured specimens, the first product of the first grinding, gives a higher percentage of nitrogen than the second; that of the latter being in both cases exceedingly low. In the products of the second grinding, the tendencies are again parallel in the two series. Here again the first product gives a higher percentage of nitrogen than the second. The third is about equal to the second; and the fourth, or bran, is in both series the highest of the six products in this respect. Following up these curious results, which show that the mechanical means employed had the tendency, even within the limits of the farinal part of the grain, to separate products of different chemical characters—we may observe, that the fluctuation in the percentages of *ash*, are in detail strongly confirmatory of the direction of the variations in the amounts of nitrogen. Thus, whether we look to the average percentages of nitrogen and of mineral matter respectively, as influenced by season, and as illustrated in the Summary Table No. I—or to the parallel amounts in the several mill-pro-

ducts as shown in Table X, we see that with a rise in the percentage of nitrogen there is, in comparable cases, one in that of the mineral matter, and *vice versâ*. If with this point in view, and carefully considering the degree of these changes as shown in our more detailed Tables, we compare together the columns of nitrogen and of ash, we find that the fluctuation in the latter as seen in Table XII, are perfectly consistent in direction with those in the former. This is more particularly observable in the products of the unmanured specimen.

The middle Division of Table XII, shows as before, a rise in the percentage of the *phosphoric acid* in the ash, as we proceed from the finer to the coarser products. The *magnesia*, too, follows the same order, the ash of the "*bran*" containing about twice as much as that of the flours of the first grinding.

In the last column of the Table XII, for the sake of comparison with the individual results in the former ones, we have the mean percentage of mineral matter for each product, of five lots of grain which were similarly experimented upon in the steel-hand-mill.

The next step in the prosecution of our inquiry would obviously have been—to separate the different proximate organic compounds, of some series of these grains and their various mill-products—to determine the amount and composition of the mineral matters associated with each—and to submit the different grains, and their mechanically separated parts, to microscopic examination. Had this been accomplished, the results would probably have been of high interest to the vegetable physiologist; and they would probably have tended to throw some light on the functional actions or special offices, of the different mineral constituents known to be essential to the growth and elaboration of vegetable products. This labour, however, from pressure of other investigations, we have hitherto been obliged to forego; though several series of the mill-products themselves (necessarily to a certain degree artificially dried), and also of their respective ashes, have been preserved with a view to the prosecution of the subject, either by ourselves or others, at some future time, as far as such specimens will allow.

A great many scientific observers have investigated the questions—of the practical yield of bread-flour from 100 of grain or meal—of the produce of bread from 100 of flour—of the amounts

of dry substance, of water, and of nitrogenous compounds, in bread—and of the changes which the flour undergoes in the bread-making process. The question as to what are the chemical qualities upon which depend the practical estimate of the miller and the baker, of the comparative values of different flours for the purposes of bread-making, has also frequently been discussed; the conclusion generally arrived at being, that it is the percentage amount of nitrogen or of gluten which rules this practical estimate. The opinion that the comparative value to the *consumer*, too, is measurable by the same standard as to chemical composition, is also pretty universal. With regard to the latter points we may at once observe, that the tendency of more recent investigations is, at least to modify, the currently adopted views. That this was desirable, the whole course of our experimental inquiry and observation, during the last twelve years, has led us to believe; and we have occasionally treated of the subject in some of its aspects elsewhere.

Without hoping to settle dogmatically, questions involving too many factors to be dealt with in such a manner, we propose now to adduce some few experiments and arguments of our own, which may have a bearing upon some of those above enumerated; and we shall also provide as summary a view as possible, in a tabular form, of such published results of others, on some of the points capable of illustration in that way.

In the following Table XIII, are given:—

1st. The results of some experiments of our own, on the amount of bread yielded by 100 of the flour taken from the different parts of the dressing-machine; in some cases using the products of each of the first 4 wires separately, and in others (19 in number), taking the products 1, 2, and 3, mixed together.

2ndly. The determinations (at 212° F.) of the dry substance, and of water, in Country, and in London bakers' loaves.

3rdly. The recorded results of others, on—the yield of flour from 100 of grain—the yield of bread from 100 of flour—and on the percentages of dry substance, and of water, in bread.

TABLE XIII.

Bread made Experimentally.

	Number of Experiments.	Particulars of the Grains. Harvest.	Bushels per Acre.	Pounds weight per bushel.	Per cent Corn in Total Produce.	Flour from 100 grain.	Bread from 100 Flour.	In 100 Bread. Dry Substance.	Water.
Product of Wire 1 ...	6					37·1	132·9	64·1	35·9
Do. do. 2 ...	8	1846 and 1847	$25\frac{1}{8}$	62·3	38·1	15·7	135·3	62·5	37·5
Do. do. 3 ...	6					12·9	138·7	61·9	38·1
Do. do. 4 ...	4	1847	$25\frac{1}{4}$	61·7	35·9	7·7	136·1	62·6	37·4
Total, or Means...	...	...	...	...	...	73·4	135·2	62·8	37·2
Products 1, 2, and 3, mixed	19	1846 and 1847	32	62·4	37·2	70·8	137·8	61·4	38·6

Baker's Bread.

	Dry Substance.	Water.
Mean of 4 Country Loaves 8 hours out of Oven	62·1	37·9
Mean of 3 London Loaves 12 hours out of Oven	64·2	35·8
Means	63·0	37·0

Recorded Observations.

	Flour from 100 Grain.	Bread from 100 Flour.	In 100 Bread. Dry Substance.	Water.
Pereira	..	128·0		
"	..	134·0		
Daubeny	82·0			
Dumas	..	128·0		
"	..	130·0	62·5	37·5
"	..	133·0		
Ure—				
Practical Average	..	133·3		
Paris (in 1835) Best Four	80·0	127·0		
Hassall	77·7			
Alison and Christison (for Scotch Poor Law Board)	..	..	62·0	38·0

Recorded Observations—*continued.*

	Nit. Mat.	Flour from 100 Grain.	Bread from 100 Flour.	In 100 Bread. Dry Substance.	In 100 Bread. Water.
JOHNSTON—					
English		75·7	150·0	56·0	44·0
English and French Ration		..	..	49·0	51·0
BOUSSINGAULT—					
English		72·0			
French		74·0			
Paris		..	130·0	64·6	35·4
Bechelbronn		..	140·0	57·1	42·9
French Ration		..	139·0		
Syrington		78·0			
Lurzer		83·0			
Dombasle		85·5			
PELIGOT		80·0			
PAYEN—					
Paris, Ordinary		..	..	64·0	36·0
,, ,, ...		..	..	62·0	38·0
French Ration		85·0	..	61·0	39·0
,, ,, ...		80·0	..	58·0	42·0
English Cubic Loaf		..	..	60·0	40·0
,, ,, ...		..	..	52·0	48·0
		Calcd.	Expt.		
MILLON—					
1.		136·0	135·0	65·0	34·98
2.		137·0	137·0	63·4	36·6
3.		131·5	132·0	63 5	36·5
4.		136·0	134·5	61·3	38·7
5.		133·0	133·0	63·3	36·7
6.		134·5	133·0	65·5	34·5
7.		135·0	134·0	66·0	34·0
8.		137·0	137·0	64·9	35·1
9.		133·0	134·0	60·5	39 5
Mean		134·8	134·4	63·7	36·3
Military		..	..	58·0	42·0
,, ...		..	..	57·0	43·0
MACLAGAN—					
Bakers' First Quality ..	7·55	..	134·7	64·25	35·75
,, Second ,, ..	7·99	..	..	65·09	34·91
Home-baked, First Quality ..	7·29	..	131 0	66·1	33·9
,, Second ,, ..	8·71	..	133·0	58·3	41·7
Unfermented, First ,, ..	7·00	..	143·0	60·5	39·5
,, Second ,, ..	7·40	..	..	58·5	41·5

Setting aside the incidental but much accounted measure of the quality of flour—colour, it may be said, that the standard of excellence of the baker, is founded on the weight of the loaf, which, consistently with proper texture and lightness, can be obtained from a given weight of flour. Leaving for the present the discussion of the question upon what point or points of chemical composition, these properties individually or collectively depend, we may observe, that so far as our own experiments on the small scale go, the quality of yielding the greatest *weight* of bread from a given amount of flour, certainly did not seem to attach to the highest separated product of the dressing-machine; which, according to the results recorded in Table X, would probably contain slightly the smallest proportion of nitrogen, and consequently the largest amount of the starch series of compounds. On the other hand, looking at the results more in detail than they are given in the Table, it appears that the products of the grain of 1846 gave a notably greater weight of bread than the corresponding products of the more highly nitrogenous grain of 1847—the grain of the former year, being admittedly a somewhat fuller and better sample than that of the latter. Judging then between the different products of the same grain, the experiments showed the weight of bread from a given weight of flour to be greater as we proceed from the less to the more nitrogenous products, so long as the comparison is made between the first three or fine flours only. The fourth product, however, containing still more nitrogen, but probably in a different condition, gave a less proportional weight of bread, notwithstanding that it also contained a considerable amount of branny particles, which it has been stated, have the property of retaining water by virtue of their structure independently of mere chemical composition. Comparing year with year on the other hand, the separate products of the grain of highest weight per bushel, of lower nitrogen, and admittedly of the best development, afforded the largest produce of bread.

Passing from the experiments on the individual products to those on the mixture of the first three of them, which would together constitute a *fine* bread-flour, we see that with this combination there was, on the average, a higher yield of bread than from either of the separate products. This was not the case taking the flours of 1846 alone; but it was remarkably so with those of 1847, the season of rather higher percentage of nitrogen; and it should be added, that whilst on the average the mixed products of

1846 represented only 68·3 per cent. of the entire grain, those of 1847 represented 71·5 per cent. Although, however, there is thus observed a tendency to increase in the *weight* of bread, the higher the percentage of nitrogen within the range of the finer flours, and especially so when mixed, yet the grains and the flours of 1846, were pronounced by an experienced miller, to be superior to those of 1847, and they would doubtless have given, on the large scale, a loaf whiter, lighter, and of better texture.

In all these trials exactly the same treatment was adopted, but as the result may be different in operating upon small and large bulks respectively, the method followed should be described. 32 ounces of flour were taken, and given weighed quantities of compressed yeast, and of salt, were always employed. Water of a uniform temperature was also used, and was worked in by a practised hand, until the dough was decided to be of the proper consistency. The weight of water taken up, was then determined. The dough was always made quite late in the evening, and after being allowed to ferment during the night, it was put into a baker's oven early the following morning. Finally, the loaves were weighed hot from the oven, and again when quite cold, towards evening. From the second weight, the increase upon the original weight of flour was ascertained; and, the percentage of dry substance in the flours being previously known, the percentages of dry matter and water in the bread were calculated, making no allowance, however, for the probably $\frac{1}{2}$ per cent. of dry substance lost by fermentation. The experiments of Millon given in the lower part of the Table XIII, as well as the conclusion of other recent experimenters, indeed seem fully to justify the assumption, that the loss from that cause perhaps need not be estimated at more than the small amount above supposed.

For the sake of comparison, and as a check to our own bread-making experiments, and calculations thereupon, three loaves were bought at random, at as many different bakers in the city of London, and four from as many in our own locality in the country; and upon half of each of these, first finely divided, the dry substance was determined in a water-bath at 212° F. It will be seen, that the mean of our own experiments with the separate products, gives, by calculation as above alluded to, 62·8 per cent. dry substance, and 37·1 water, in the bread; and that with the products 1, 2, and 3 mixed, gave 61·4 dry matter, and 38·6 water.

The four country bakers' loaves (in July 1856—probably from wheat of 1855), gave 62·1 dry, and 37·9 water; and the three London ones 64·2 dry, and 35·8 water. It is thus seen, that our own results from the various flours of grain from two different harvests, agree very closely with those of the country bakers' bread from a third. They, together, indicate an average of 37 to 38 per cent. of water in the bread. The London bakers' loaves, which, however, had probably been four hours longer out of the oven than the country ones, gave 64·2 of dry = 35·8 of water. Upon the whole, then, these experiments, from the flours of three different seasons, indicate a probable average range of from 36 to 38 per cent. of water in bread; and, taking an average of 15 per cent. water in flour, and assuming the loss of dry matter by fermentation, and the gain by fixed saline matter added, to about neutralize each other, this would be equivalent to, from 132·8 to 137·1 parts bread for 100 of flour.

A reference to the recorded results of others, as given in the Table (XIII), will show that this average of 36 to 38 per cent. of water in bread, agrees very closely with the estimate of Dumas; with that of Payen, for the ordinary bread of Paris; with that of Boussingault, for Paris bread; with the mean of four kinds of fermented bread experimented upon by Dr. Maclagan; with that of nine by Millon; and with the estimate of Alison and Christison. The estimate by Payen, of 40 to 48 per cent. of water in the English cubic loaf, is undoubtedly too high for English bakers' bread as usually sold. The estimates by Johnston, of 44 per cent. water in English bread, and of 51 per cent. in English and French ration-bread, are also, no doubt, too high. The results of Boussingault in France agree with our own in England, in showing country bread to contain, usually, more water than that of the cities. Ration-bread seems, according to most observers, to be moister than that in ordinary use. To conclude on this point, although it is very desirable to have a proper estimate of the probable average proportion of dry substance contained in the most important article of the food of our population, yet it is obvious that many circumstances must influence the amount in individual cases. The length of time that the bread has been withdrawn from the oven, must of course be taken into account; but in fixing general averages, perhaps it is better to take it within the first twelve hours, as this will best represent the weights as

delivered by the baker, and, consequently, those estimated as consumed.* It must be remembered, too, that the character of the ripening season greatly affects the quality of the flour, and in giving from the results of others as well as of ourselves, a probable average of 36 to 38 per cent. water, or 62 to 64 per cent. of dry substance in bread, we would at the same time remark, that all our own special data, are derived from experiments on the produce of three seasons of higher than average maturing character.

That the *season*, independently of either soil or manuring, may very much influence the percentage of nitrogen in one and the same description of grain, even in the same locality, is amply illustrated by the results in Tables I and III, given at the commencement of this paper. It cannot be wondered at, therefore, that different localities or countries, should yield us grains showing a wide range of variation in their percentages of nitrogenous compounds. M.M. Rossigneau, Boussingault, Millon, and Peligot have examined many of the characteristic wheats of commerce, and we propose here to subjoin some additional facts relating to this branch of the subject.

In the following Table (XIV) are given the mean results of a great many determinations, by the mechanical method, of the *gluten* in flour, by Mr. W. Constable, of Brighton. It is admitted that this method is an uncertain one, and it is, of course, quite incompetent to indicate the *total nitrogenous* substance of the flours. However, we believe the experiments to have been made with great care and uniformity of manipulation, and, as they are also consistent with results of another kind, they are well deserving record. It may be premised that, whilst the method in question is liable to a little depreciation in the amount of gluten by loss in the washing—especially when the substance itself is of an inferior character—yet, on the other hand, the drying is more likely to be in error in the other direction. These two sources of error, therefore, so far as they operated in the experiments, would tend to neutralize each other. It may be added, that not the least interesting part of Mr. Constable's results, is that he, consistently with the observations of Peligot and others, establishes a very wide range in the *character* of the gluten obtained from different flours,

* It should be stated, however, that, if the fresh weight of the 7 baker's loaves examined were assumed to be 4 lbs. each, as it should have been, then the dry matter which the loaves contained was, on the average, only equal to 60½ per cent; the water, on the same calculation, being, of course, 39½ per cent.!

as to colour, tenacity, elasticity, and so on. Mr. Constable's results, with which he has kindly furnished us, are recorded by him seriatim, in the order in which they were obtained, and without any special reference to the point for the illustration of which we here adduce them. It will be seen that, in our Table, we have classified the results according to their reputed locality of growth or shipment, and arranged the *means* so obtained somewhat in the order of latitude, ranging from north to south, adopting the same general arrangement for the European and American samples respectively.

TABLE XIV.

Percentage of Gluten in different Flours.

Mean Results.

Reputed Localities of Growth or Shipment.	Number of Experiments.	Mean Gluten Per Cent.
America—		
Canada	6	9·8
Genessee (New York)	7	9·8
Other New York	7	10·1
Ohio	18	11·8
Maryland	3	11·3
Richmond (Virginia)	8	11·8
George Town (South Carolina)	18	13·7
New Orleans	1	13·4
Miscellaneous	11	9·35
Mean	79	11·4
North Europe—		
Dantzig	4	8·9
Hamburg .. .. Stettin .. .. Pomerania	8	10·3
South and East Europe—		
Tuscany .. .. Spain .. .. Portugal	8	10·3
Black Sea, Soft	2	12·5
Black Sea, Hard	9	14·9
Mean	31	11·6
England—		
White	45	10·8
Red	13	10·4
Not Specified	45	10·5
Mean	103	10·7

It cannot fail to be observed, that there is a general tendency in the specimens from both the European and American continents, to increase in the percentage of gluten, proceeding from the north to the south. It may therefore be concluded that, among other circumstances, a relatively high temperature at the ripening period is favourable to a high per-centage of gluten. The mutual adaptations of heat and moisture, throughout the various stages of the progress of the plant, are, however, so almost infinitely varying, even from season to season, in one and the same locality, that it is not surprising there should be many exceptions to any such sweeping generalization as the one here indicated, in regard to widely differing localities. A study of the variations in the character of the crop, and in the composition of the grain grown from year to year in our experimental field, side by side with the varying circumstances of root and leaf supply of moisture, and of temperature, is sufficient to show how numerous, and how indeed ever changing in their mutual relations, are the factors which lead to one or another order of development in the growing plant.

We have at various times determined the nitrogen in individual specimens of foreign wheat which have come in our way, and recently, through the kindness of Mr. W. J. Harris, of Fenchurch Street, London, we have been provided with a series of characteristic samples, the result of the examination of which we had hoped to embody in this paper. Unfortunately, the laboratory work is not sufficiently completed to allow of this, any further than by a few general remarks on the tendency of the results already obtained. This tendency, from the examination of a series of contrasted samples, is fully to confirm the indications of Mr. Constable's results as to general influence of latitude, or locality, on the nitrogenous percentage of the grains. There are, however, as above inferred, some interesting and instructive exceptions brought to light. It is obvious, too, that both soil and variety, must have much to do with the character of the grain; and that to elicit without exception, the influence due to climate alone, the same description of wheat should be grown in as far as possible similar soils, in different localities, for a series of years consecutively. In defect of specimens of this kind, we must to a certain extent rely on the assumption, that those descriptions will be generally cultivated in a particular locality, which experience has shown to be most adapted to its climate and other characters, and that hence the qualities of the

grains, will be at least some indication of the general tendencies of the climatic circumstances which have yielded them.

It may be remarked, that among the American specimens examined by Mr. Constable, the Genessee is seen to contain the lowest average percentage of gluten, yet it is one of the most highly esteemed of the American flours imported into this country. Again, among the foreign European samples enumerated, the Dantzic yielded the smallest percentage of gluten, whilst it has above all the highest range of value in the English market. The soft Spanish is perhaps the next in order of value among the imported European wheats, and we may observe that it is also one of the lowest in percentage of nitrogen which we have yet examined. On the other hand, the flours from many of the *highly* nitrogenous foreign wheats, have the undoubted character of imparting great "*strength*" to the dough, and for this purpose, they are much valued to *mix* with weaker flour; especially with that from grain which has been imperfectly developed and matured. Some of the most important of these highly nitrogenous wheats are, however, both inferior in the colour of their flour, and very hard and horny; and owing to the inappropriateness of the English method of milling, to the defective whiteness of the flour, and of the bread, and to the somewhat close texture of the latter, other flours of lower percentages of nitrogenous compounds have, notwithstanding this great "*strength*," a higher character when used alone for bread-making purposes. These highly nitrogenous wheats are chiefly imported from Russia, and independently of a high ripening temperature, they are for the most part grown on very rich soil, and sown in the Spring. On this point it is worthy of notice, that home-grown Spring wheat, has sometimes the character of imparting strength to the flour of an inferior Winter wheat, and in the only instance of this kind which we have examined, the reputed stronger (Spring) wheat, had the higher percentage of nitrogen.

It may be stated generally, that the highly nitrogenous foreign wheats, have the admitted character of imparting strength to inferior flour; and they are thus highly valued for the purpose of admixture with home-grown grain imperfectly developed and matured. These highly nitrogenous imported wheats have, as the rule, been matured under a much higher temperature than our own; their nitrogenous constituents would appear to be in larger proportion in the form of gluten; and it is in wheats so ripened,

that the higher percentage of fatty matter is also found, the proper blending of which, according to the experiments of Peligot, considerably affects the physical characters of the gluten. The opinion of Peligot—indeed of other recent investigators, and in this we fully concur—is, that the measure of value of different flours for the purposes of bread-making, is certainly much more dependent on the *condition* of their constituents, than on their mere percentage amount of nitrogenous compounds. This high *condition* of the nitrogenous, and also the other compounds, would seem to be alike possible in wheats of high and of somewhat low percentage of nitrogen—provided, other things being equal, they have been well developed, and ripened at a high temperature; whilst, when this is so, an undoubted preference is given to the less nitrogenous grains. This is partly due to the latter being generally softer, and more amenable to current milling methods; and partly to the widely-differing structural character of the farinal matter, by virtue of which the flour not only makes a better and more workable dough, but the bread produced is of superior texture and lightness—conditions which all analogy would lead us to conclude, must materially aid its digestion and assimilation, and consequently so far increase its value as food.

A high percentage of nitrogenous compounds, provided the grain be well-developed and matured, and not so hard as to offer mechanical obstacles to fine division and easy separation of the bran in the mill, will tend to a great weight of bread, and a good quality as to texture. It would appear, however, that a smaller percentage, if with equally high elaboration, will tend to a similar result as to weight, and to even higher qualities as to texture and whiteness. Within the limits of our own island, however, on the average of seasons, the better-elaborated grain will probably be the less nitrogenous,* though the nitrogenous matter it does contain, will be in a high condition as to elaboration, and to its mutual relations, structural and chemical, with the other constituents of the flour. Hence it comes to pass that, as our home-grown flours go, those which are the best in the view of the baker, will frequently be those having a low *percentage* of nitrogenous compounds—a higher *condition* more than compensating for the

* This is, however, not always the case; and, had we extended our review beyond the ten years to which Tables I and III refer, we should have found, in the season of 1855, both high development and maturation of grain, and high percentage of nitrogenous compounds. Of the cases included in our survey, the season of 1847, afforded in the highest degree the combination of characters here referred to.

higher percentage of nitrogen, generally associated as it is in our climate, with an inferior degree of development and maturation.

We conclude, then, that condition of *maturation,* or perhaps rather *elaboration,* as well as mere percentage composition, should be theoretically, as it is practically, admitted as an essential element in estimating the relative qualities of different wheats or flours, for bread-making purposes. The opinions of some of the most recent, and perhaps the most competent observers, certainly point in the same direction as the one here indicated. Still, the current opinion derived from several of our standard works, would seem to be, that a high percentage of nitrogenous compounds should be taken as an almost unconditional measure of value.

But besides the frequently reiterated statement that the baker's estimate is founded on the amount of the gluten, it is also pretty generally maintained, that it is the amount of this, or of the nitrogenous constituents collectively, which determines the comparative values of different flours or breads, to the *consumer.* With regard to those foreign wheats which have their nitrogenous substance in a highly-elaborated condition, and favourably related to the other matters, and in which the whole is structurally fitted for easy milling, and to yield a light and easily-digestible bread, we would not say that, with such, a comparatively high *percentage* also of the nitrogen, might not be an additional point of value. But, even with the foreign wheats, it is but a small proportion that combine these several qualities; whilst those which have the most of the others, have, generally, less of the *amount* of nitrogenous substance. With home-grown wheats, too, as already said, information at present at command tends to show, that high percentage of nitrogen is, frequently at least, associated with *low condition of elaboration* of the constituents of the grain, yielding an inferior bread-flour—and thus, though from opposite causes to those which depreciate the richer nitrogenous grains of the higher-ripening temperatures, a less valuable food.

Let it be conceded, then, that condition, or elaboration, must affect the digestibility and assimilability of our food. But, we think it may be inferred, yet on other grounds, *that, as flours go,* the richer in the more directly respirable and fat-forming compounds, will generally be more valued as food.* The following Table (for

* There is experimental evidence to show, that the nitrogenous constituents of food may serve one or both of these offices; but, when in excess, probably at a greater cost to the system.

some of the data of which we are indebted to Dr. Playfair), showing the estimated average percentage of nitrogen and of carbon in a number of standard articles of food, and also the relation in them of the one constituent to the other, will aid us in illustrating our meaning :—

TABLE XV.

Estimated Average Composition of Standard Articles of Food.

Foods.	Per Cent.			Nitrogen to 100 Carbon.
	Dry Substance.	Carbon.	Nitrogen.	
Meat (fresh)	45·0	30·0	2·0	6·6
Bacon (green)	80·0	57·0	1·13	2·0
„ (dried)	85·0	61·0	1·4	2·3
Suet or Butter	85·0	68·0	0·0	
Milk	10·0	5·4	0·5	9·3
Cheese	60·0	36·0	4·5	12·5
Flour (wheaten)	85·0	38·0	1·72	4·5
Bread	64·0	28·5	1·29	4·5
Maize	87·0	40·0	1·75	4·4
Oatmeal	85·0	40·0	2·0*	5·0
Rice	87·0	39·0	1·0	2·56
Potatoes	25·0	11·0	0·35	3·2
Vegetables (succulent, average) ..	15·0	6·0	0·2	3·3
Peas	85·0	39·0	3·65	9·4
Sugar	95·0	40·0	0·0	
Cocoa and Chocolate	92·0	56·2	2·0	3·6
Beer or Porter ..	9·5	4·5	0·01	0·2

By this Table it is seen, that wheaten flour and bread contain as high a proportion of nitrogen to carbon as most of the current articles of food of our working population, excepting the important items of fresh meat, milk, and cheese. Were we to ask, to what staple articles the working man next resorts, when his means allow him to add other foods to his main diet of bread?—the answer would be, cheese, bacon, and, perhaps, butter; and we think it would further be, that his preference would generally be for the bacon. The Table shows that, so far as he took cheese, he would considerably increase the proportion of the nitrogen to the carbon he so consumed. The amount of it he would eat would, however, be less than that of bacon, and in the latter he would only consume half as much nitrogen, in proportion to the carbon, as he would in bread alone. In fat, or butter, he would have no nitrogen

* Scotch oatmeal would range higher than this.

at all, so that the addition of either of these to his flour or bread, would still further reduce the proportion of nitrogen to carbon in his food. But all these substances, besides their respirable carbon, have a large proportion of respirable hydrogen, due to their *fatty substance.* Even cheese, which contains the least amount of this, has, nevertheless, a very considerable percentage of it; bacon much more; whilst fat and butter, excluding their water, are, of course, wholly composed of it. If, therefore, we take into calculation the respirable hydrogen, it will be seen that the *respiratory capacity* (so to speak) of the cheese, would be much higher relatively to the *flesh forming,* than the relation to the carbon alone, as in the Table, would indicate. In the bacon, on the other hand, the relation even of the carbon alone to the nitrogen, is much greater than in bread; and, if we further take into account its respirable hydrogen, its respiratory, relatively to its flesh-forming capacity, will appear still greater in comparison with the bread. Lastly, even taking the case of fresh meat, so large is its amount of fat, and, therefore, of respirable hydrogen, that its respiratory and fat-forming, relatively to its flesh-forming capacity, would be much higher, as compared with bread, than the figures in the Table, relating to carbon alone, would show.

From these considerations we think it may fairly be concluded, that the first more urgent call of the system of our under-fed, or only bread-fed, working man, is for an increased supply of respiratory or fat-forming, rather than of flesh-forming, constituents of food. Indeed it is to *fat itself,* in some form, that he first resorts.

If, then, the first demand of the system be generally for more of the more directly respirable or fat-forming material, than bread alone supplies:—if the foreign wheats of more than average percentage of nitrogen have, frequently, structural characters which render them with greater difficulty made into an easily-digestible bread:—if the more highly-nitrogenous wheats of our colder summers have their constituents frequently in a less highly-elaborated condition:—and if, finally, the introduction of more of the nitrogenous constituents of our grain into the bread-flour, generally introduces at the same time branny particles which cause the food to pass in too large a proportion undigested from the body—it would appear, that the standard of value of food-stuffs as they go, according to their nitrogenous percentage, is, at least, only conditionally correct, and that the current views on the point require to be somewhat modified.

From all the data at our command we have adopted 1·29 as the probable average percentage of nitrogen in wheaten bread. That

taken by Dr. Maclagan is from 1·1 to 1·2; and that by Playfair and Payen about 1·1. These amounts represent respectively about 8, 7½, and 7 of nitrogenous compounds.* It will not be supposed that, because, from the facts adduced, we are led to believe that, in addition to such a bread as is here assumed, the first call of the system of the working man would be for more of respiratory and fat-forming material, we would therefore deny the advantage of an increased supply of nitrogenous constituents also. We would, however, submit, as worthy of reflection, that, whilst the relation of nitrogen to 100 of carbon in wheaten flour and bread is 4·5, that in the average of the food consumed, taking eighty-six cases, divided into fifteen classes, and including both sexes and all ages, was only 5·34. These dietaries included many which were exceedingly liberal, so far as the nitrogen supplied was concerned; yet a careful consideration of their details showed that, taking into calculation their respirable hydrogen, the relation of purely respiratory, or fat-forming, to flesh-forming material, in most of these numerous dietaries, would be nearly as great in bread. Indeed, it would appear that, that which is admitted to be a superior class of diet, is distinguished much more by including a certain amount of the important non-nitrogenous constituents, in the condition, and state of concentration, as in fatty matter—and of the nitrogenous ones, in the high condition, as in animal food, than by the higher proportion of its flesh-forming to its more exclusively respiratory and fat-forming constituents.

Appendix.

On the assumption that it is established by others (for we have not ourselves any direct experiments on the point), that the loss of dry substance, by the panary fermentation, is less than one, and, perhaps, less than 0·5 per cent. of that of the flour employed, it is obvious that the number of loaves of a given weight obtained from a sack of flour (280 lbs.) being given, and the per-centage of water in the flour also known, we could easily estimate, within very narrow limits, the per-centage of dry substance in the bread produced. The per-centage of dry matter in bread, thus determined by calculation from the actual or assumed amount in the flour, will be too

* These estimates have reference to the bread from rather fine flour; that from the coarser flours contains rather more of nitrogenous matters.

high by the unknown quantity lost by fermentation, and too low by the amount of salt, or other saline matter, added. On the latter point it may be stated, that about 4 lbs. of salt to the sack of flour is equal to about 1 per cent. in the bread. Indeed, assuming the loss by fermentation as above, and taking such data as we possess as to the usual amount of mineral matter added by the baker, we are disposed to conclude, that the dry matter in bread, calculated as above supposed from the amount of dry substance in flour, and the amount of bread it yields, would be too low by from 0·5—1 per cent., depending on the quantity of the extraneous mineral matter used.

Again, if the whole of the loss by the changes during fermentation be less than 0·5 per cent., and if these, as is known to be the case, mainly affect the non-nitrogenous constituents, we can, in the same way as for the dry matter and the water, estimate pretty exactly the amount of *nitrogen*, or of *nitrogenous compounds*, from the amount of the one or the other in the flour employed.

Frequently, however, the estimates which are given by one and the same authority, for the composition of wheaten-flour and bread respectively, do not seem to bear a proper relation to each other. We have thought, therefore, that it might be useful to give, as an appendix to our paper, a tabular form, showing the yield of bread from 100 of flour, and the per-centages of dry matter, water, nitrogen, or nitrogenous compounds, in the former—assuming any given number of four-pound loaves to be obtained from a sack of flour, and assuming also given probable amounts of water and of nitrogen in the flour. This is accordingly done in Table XVI., which follows.

We need only further say that, with fermented baker's bread of good quality, ninety-five *really four-pound loaves* to the sack of flour, is a yield perhaps very seldom reached.* It would appear, however, from published statements, that of unfermented bread, more than 100 four-pound loaves may be obtained from the sack of flour. It is worthy of remark, that if this be the case, and if the loss by the fermentative process be really so small as is now supposed, the gain in weight by the non-fermenting method, is only a gain of *water retained in the bread.* Unless, therefore, the unfermented bread be better adapted for digestion or assimilation, or be sold at a correspondingly lower price, the consumer will be a considerable loser by the purchase of the unfermented loaf.

* We speak of course of *pure wheaten bread.*

TABLE XVI.

Showing the Composition of Wheaten Bread, calculated from the Quantity of Bread obtained from a given Weight of Flour, and from the Composition of the Flour.*

Number of 4-lb. Loaves obtained from a Sack (280 lbs.) of Flour.	Equsl to Bread for 100 Flour.	Per Cent. Dry Matter and Water in the Bread.						Per Cent. Nitrogen, or Nitrogenous Compounds (Gluten, Albumen, &c.), in Bread. (Nitrogenous Compounds = Nitrogen × 6.3).							
		If 16 per Cent. Water in Flour.		If 15 per Cent. Water in Flour.		If 14 per Cent. Water in Flour.		If 1·65 Nitrogen (=10·4 Nit. Compound) per Cent. in Flour.		If 1·7 Nitrogen (=10.7 Nit. Compound) per Cent. in Flour.		If 1·75 Nitrogen (=11·0 Nit. Compound) per Cent. in Flour.		If 1·8 Nitrogen (=11·3 Nit. Compound) per Cent. in Flour.	
		Dry Matter in Bread.	Water in Bread.	Dry Matter in Bread.	Water in Bread.	Dry Matter in Bread.	Water in Bread.	Nitrogen in Bresd.	Nitrogenous Compounds in Bread.	Nitrogen in Bread.	Nitrogenous Compounds in Bread.	Nitrogen in Bread.	Nitrogenous Compounds in Bread.	Nitrogen in Bread.	Nitrogenous Compounds In Bread.
90	128·6	65·3	34·7	66·1	33·9	66·9	33·1	1·28	8·06	1·32	8·32	1·36	8·57	1·40	8·82
91	130·0	64·6	35·4	65 4	34·6	66·1	33·9	1·26	7·94	1 31	8·25	1·35	8·50	1 38	8·69
92	131·4	63·9	36·1	64 7	35·3	65·4	34·6	1·25	7·87	1·29	8·13	1·33	8·38	1·37	8·63
93	132·8	63·2	36·8	64·0	36·0	64·7	35 3	1·24	7·81	1·28	8·06	1·32	8·32	1·35	8·50
94	134·3	62·5	37·5	63·3	36·7	64·0	36·0	1·23	7·75	1·26	7·94	1·30	8·19	1·34	8·44
95	135·7	61·9	38·1	62·6	37·4	63·4	36·6	1·22	7·69	1·25	7·87	1·29	8·13	1·33	8·38
96	137·1	61·3	38·7	62·0	38·0	62·7	37·3	1·20	7·56	1·24	7·81	1·28	8·06	1·31	8·25
97	138 6	60·6	39·4	61·3	38 7	62·0	38·0	1·19	7·50	1·23	7·75	1·26	7·94	1·30	8·19
98	140·0	60·0	40·0	60·7	39·3	61·4	38·6	1·18	7·43	1·21	7·62	1·25	7·87	1·29	8·13
99	141·4	59·4	40·6	60·1	39·9	60·8	39·2	1·17	7·37	1·20	7·56	1·24	7·81	1·27	8·00
100	142·8	58·8	41·2	59·5	40 5	60·2	39·8	1·15	7·24	1·19	7·50	1·22	7·69	1·26	7·94
101	144 3	58·2	41·8	58·9	41·1	59·6	40·4	1·14	7·18	1·18	7·43	1·21	7·62	1·25	7·87
102	145·7	57·6	42·4	58·3	41·7	59·0	41·0	1·13	7·12	1·17	7·37	1·20	7·56	1·23	7·75
103	147·1	57·1	42·9	57·8	42·2	58·5	41·5	1·12	7·05	1·15	7·24	1·19	7·50	1·22	7·69
104	148·6	56·5	43·5	57 2	42·8	57·9	42 1	1·11	6·99	1·14	7·18	1·18	7·43	1·21	7·62
105	150 0	56·0	44·0	56·7	43·3	57·3	42·7	1·10	6·93	1·13	7·12	1·17	7·37	1·20	7·56

* The Figures in the Table should, of course, be taken subject to the qualifying remarks which have been made. It is obvious that the Form can easily be extended to include any further or intermediate ranges of produce of bread, or composition of Flour.